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SIXTH SPACE UTILIZATION SYMPOSIUM

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SIXTH SPACE UTILIZATION SYMPOSIUM

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A STUDY ON FUNCTIONAL ALLOCATION OF ROBOT SYSTEMS IN ORBIT

Fumiaki SANO and Yuuki YOSHIE

Space Station Department,
Ishikawajima-Harima Heavy Industries Co.,Ltd.
6-2 Marunouchi 1-Chome, Chiyoda-ku, Tokyo 100

The needs for the space robot systems are increasing all over the world. They are expected to support platforms or space factories deployed in the space infrastructure based on the Space Station Freedom around the turn of the century.

The study on the functional allocation of robot systems is important, because many kinds of systems in orbit involving the space robots may be considered.

In this report, the mission analyses, the system studies and the study on the functional allocation were carried out on the space systems in orbit involving the space robots, sponsored by the National Space Development agancy of Japan.

Missions of space robots were extracted every space crafts which will be necessary for space infrastructure from 2000 to 2010. The intensity of necessity, the time and the frequency of every extracted missions were discussed.

Categorization of space systems was performed using 5 criteria such as moving ability, working environment, ability to perform plural missions, autonomous level and ability to carry massive objects. And 56 configurations of space systems were considered by means of the extracted characteristics of space systems belong to each of the categories.

The study on the functional allocation of the space systems were performed to minimize the cost per performance in space development, and a proposal how to develop the space robots was offered.

Key words: Space robot, Space infrastructure

A STUDY ON THE DEVELOPMENT OF SPACE ROBOTICS

Sadao Mikami	TECHNOVA Inc.
Takashi Uchiyama	Fujitsu Laboratories, Ltd. Kawasaki
Takeo Ohmichi	Mitsubishi Heavy Industries, Ltd. Technical Headquarters
Keiji Goma	Toshiba Corp. Komukai Works
Norimasa Yoshida	Mitsubishi Electric Corp. Kamakura Works
Dr. Makoto Nagatomo	Institute of Space and Astronautical Science Yoshinodai, Sagamihara, Kanagawa

The purpose of the development of space robotics is for humans to make effective use of the space environment. This study was carried out and compiled by space development research specialists and robotics research and development experts. During the first phase of this study, a number of robotics-related research areas were selected from the entire range of space development missions under consideration.

Next, the optimum research team sought the optimum approach to space robotics development based on advanced robot development research knowledge information. Given these results, the space robotics capabilities and functions were considered based on the productivity of space operations in the context of future space development.

The recognition of the need for a concept calling for increased robotic autonomy/intelligence and a wider range of applications led to a proposal for modular space robotics. This proposal calls for increased efficiency of the development operations and concrete ideas related to the increase of robot intelligence and the widening of the range of applications.

An investigation of how to clarify the development of the main technologies was conducted based on the proposal development concept. The study participants were able to specify the robot architecture, and the software packages, etc. of each robot subsystem.

An image of the partitioning and linkage of the total system was clarified, with due consideration given to the adaptability of the software package to the individual system hardware. Likewise, an investigation was conducted to determine the simulators, facilities, and experiment items required for the evaluation of the robots to be developed.

Based on the above, an outline of the fundamental development concept and approach was constructed.

Lastly, the expected spheres of activity of space robots and an overall image of the results which can be anticipated have been delineated. In order to expand upon the above conclusions in a more concrete form, we have proposed the formation of a space robot development center. This will hasten the development of the above-envisioned space robots necessary for the development of space.

Report of Research Forum on Space Robotics and Automation

Yoji Umetani(Tokyo Institute of Technology)
Tsutomu Iwata(NASDA), Kiyoshi Ueno(JSUP)

The necessity of robotics and automation in space is now universally recognized worldwide. Also, in the symposium cosponsored by AIAA/NASA held in Washington, D.C., on November 1988. a considerable number of concrete reports on the present state of development and the plans of development of space robotics were made by Japan, the U.S., Europe, U.S.S.R. as well as by other countries.

This report is the Executive Summary of the achievements in the second year of the "Research Forum Space Robotics and Automation" (abbreviated name: Space Robotics Forum). The Space Robotics Forum is a research and investigation group of space specialists and robotics researchers, and carried out the activities by organizing respective working groups on two themes which were proposed last fiscal year. The first theme is " Assembling of space structures in orbits", and the second theme is "Construction of a space experiment module (COSMO-LAB)". As the activities for the investigation, the investigation and research meetings as the monthly meetings and the lecture and the investigation of the trend carried out by traveling to U.S.A. were held. The achievement based on these activities are described in this report.

This Forum is composed of 73 members, and most of them belonged to either of two working groups and also participated in the research activities. Besides, in the Planning Committee of this Forum, in addition to the decision and deliberation of the course of activities, the editing and writing of Chapter 1 were carried out.

Key words : Space Robotics, Automation

INFORMATION SYSTEMS IN SPACE INFRASTRUCTURE

Hiroshi ANEGAWA,
Tsukuba Space Center, National Space Development Agency of Japan
2-1-1 Sengen, Tsukuba, Ibaraki 305

Akira ASHIDA and Hirokazu IHARA
Space Systems Division, Hitachi, Ltd.
4-6 Kanda-Surugadai, Chiyoda-ku, Tokyo 101

In a future stage, space activities will be progressed, building the space infrastructure. Space information systems come to be important for releasing the ground operation control from complicated control. Future type spacecrafts such as platforms, OSV/OMV, OTV, etc. have new features of multimissions, telescience/teleengineering, orbital service, on-orbit assembly, etc., so they should be made with inteligent architecture. The space information system for the space infrastructure is desired to be constructed with autonomous spacecrafts.

As one candidate of the spacecraft information system, the autonomous decentralized system is introduced, which was originated from a system concept of living things.

An optic data bus technology is most preferable to the spacecraft information network because of its EMI resistance, vide bandwidth and small sizing/light weight. Informations flowing in spacecrafts are code, burst, audio and video. The suitable switching of such information is as follows:

Packet switching for code and burst information and
Circuit switching for audio and video information.

Information topology for the new type spacecraft is presented as one candidate. A function unit of a spacecraft is called 'cluster' which includes network control processors connecting to subsystems. The optic data bus is constructed by connection between clusters. Optical switching technology is the key of this data bus.

Key words: Space Information System, Optic Data Bus, Spacecraft Data Bus, Autonomous Decentralized System, Space Infrastructure, Platform, Future Type Spacecraft, Information Topology

A FURTHER EXPERIMENTAL STUDY ON DYNAMIC MASS-MEASUREMENT UNDER A TWO-DIMENSIONAL WEIGHTLESS CONDITION

- An Approach to Establishing A New Technology of Mass-Measurement under Weightless Conditions -

Shozo TSUJIO, Toshiro ONO, Katsutoshi KURIBAYASHI and Koichi OSUKA

Department of Mechanical Engineering
College of Engineering
Osaka Prefectural University
Mozu-Umemachi, Sakai, Osaka 591

The authors have already proposed a method of dynamic mass-measurement under weightless conditions. This method uses an equation of motion of a mass-measuring device, which consists of a mechanical mass-spring oscillator and its supporting frame. Appropriate motion signals of the mass-measuring device are needed in this dynamic mass-measurement method. However, they can be easily detected by using accelerometers and displacement sensors.

Preliminary experimental studies were conducted to indicate the feasibility and effectiveness of the proposed method. The mass-measuring device used in the experiments was placed on an experimental work bench (static environment). Other experiments were carried out mounting the device on a vibration testing machine (dynamic environment).

In this study we have performed further experiments to simulate dynamic mass-measurement under a two-dimensional weightless condition. A float table with an air-bearing on a horizontal base was provided to produce free motion in a two-dimensional plane. The mass-measuring device having a horizontal mechanical oscillator was mounted on the float table; the whole measuring device was then considered to be under a two dimensional weightless condition.

The mass-measuring device on the float table oscillated periodically in the second mode, because of the two degree-of-freedom dynamic system, where the first mode did not, as it was rigid. In this two dimensional weightless condition, the mass-measurements were carried out.

The experimental results showed that the total measurement error was smaller than 0.8 % of the 0.6 kg weighing capacity.

Alternative experiments were carried out constraining the horizontal movements of the float table. There was no significant difference in the total measurement errors between this experiment in the constraint condition and the experiments under the weightless condition described above. These results show the feasibility and effectiveness of the dynamic mass-measurement under weightless conditions.

Key words: Weightless Condition, Micro-Gravity, Mass Measurement, Dynamic Measurement Method, Sensor-Dynamics Identification, Experiment, Accelerometer, Displacement Sensor

STUDY OF MATERIAL EXPERIMENT SAMPLE SAFETY IN FMPT

Masayuki Sugawara*,Toshihiko Yamawaki*,Sadanori Kawano*
Yukio Kitamura** and Kanjo Tachiyama**

* National Space DEvelopment Agency of Japan
** Ishikawajima-Harima Heavy Industries Co.,Ltd.

National Space Development Agency of Japan(NASDA) is promoting First Material Processing Test(FMPT) Project which will be launched in 1991 using Spacelab. To conduct Space Experiment in human environment,Safety should be considered as an significant factor.
We take sample safety in furnaces as an example and report how we have studied it in FMPT.

Key words:FMPT,Sample Safety,Spacelab

STUDY OF DESIGN REFERENCE MISSIONS FOR SAPACE STATION PROJECT

Shinichi YODA & Yoshinori FUJIMORI

National Space Development Agency of Japan (NASDA)
Shiba, Minato-ku, Tokyo 105

Hiroaki HASHIMOTO

Japan Space Utilization Promotion Center (JSUP)
Nishi-Waseda, Shinjuku-ku, Tokyo 169

It takes many years to develop the Space Station/experiment modules and certain missions have to be assumed temporarily as design conditions for the development prior to the final selection of the experiment themes actually executed there.

In 1988, NASDA has established the design reference missions based on 328 themes gathered for preliminary design of Japanese Experiment Module, JEM, the discussions at Workshops, results of the past space experiments etc.

This is to report the process to establish the design reference missions.

Key words: Space Station, Space experiment, Mission, JEM

SPACE STATION OPERATIONS AND UTILIZATION CONCEPT

Hajime NISHIMURA and Kiyoshi HIGUCHI

National Space Development Agency of Japan (NASDA)
Shiba, Minato-ku, Tokyo 105

Isao NAKANISHI

Japan Space Utilization Promotion Center (JSUP)
Nishi-Waseda, Shinjuku-ku, Tokyo 169

Examination situation of Operations and Utilization Concept of Japanese Experiment Module (JEM) is introduced based on Space Activities Commission AD-HOC Committee Report, user opinions at Space Station Utilization Workshop etc. and examination situation of NASA and ESA. For example, what is considered the usage of JEM, what work must be done and what is examined JEM operations system and user support system.

Key words: Space Utilization, Space Station, JEM

Project of boarding "MIR" Russian Space Station

TOKYO BROADCASTING SYSTEM, INC.
SPACE PROJECT DEPT.
Tetsuo Aoki
Ichiro Sasaki
Masatoshi Tashita
Atsushi Oketa

March 27, 1989, Tokyo Broadcasting System, Inc. (hereinafter TBS) and GLAVKOSMOS, attached to SOVIET MINISTROV, U.S.S.R. (hereinafter GLAVKOSMOS) reached an agreement on a space flight of a Japanese cosmonaut before the end of 1991. According to the project, one cosmonaut selected by TBS is to be launched in "SOYUZ" spacecraft and stay in "MIR" space station for six days before returning to the earth.

There is no doubt that, in the forthcoming new century, there will be many productive activities in the space, and that space flights will be open for ordinary people as well. With such new era close at hand, we believe it is one of the important duties for us broadcasters who play a role in the mass media, to report to the public the firsthand experiences of a journalist cosmonaut who, ahead of the times, challenged space travel, a dream of human beings.

This project of participating the space flight based on the agreement between TBS and GLAVKOSMOS should be considered the comprehensive program of the theme of the space development. This project is scheduled to be implemented as part of TBS'activities commemorating the fortieth anniversary of its foundation.

MIR, SOYUZ, Japanese cosmonaut

Space Life Science and Molecular Science

M. Shimizu, T. Hasegawa & H. Himeno

Institute of Space and Astronautical Science
Yoshinodai, Sagamihara, Kanagawa 229

The presence of life on earth may depend on the dualistic character (hydrophobicity and hydrophilicity) of nucleic acid bases and amino acids. Stacking of bases in water decides the conformation of their hydrogen bonding donors and acceptors to make possible to molecular recognition of hydrophilic amino acids. A complex of anticodonic bases and discriminator base can accept the cognate hydrophobic amino acids. These relationships appears to explain the universal genetic code.

Since biomolecules are observed to be abundant in the solar system (meteorites and comets), necessity for the generation of life could be discussed in terms of the above molecular recognition.

Key words: Nucleic Acid, Protein, Genetic Code, Space Life Science

FORMATION OF BIOORGANIC COMPOUNDS IN PRIMITIVE EARTH ATMOSPHERE AND IN COMETS --SIMULATION EXPERIMENTS IN THE LABORATORIES TO EXPERIMENTS IN SPACE--

Kensei KOBAYASHI, Hiroshi YANAGAWA,* Tairo OSHIMA,** and Masahiko TSUCHIYA

Department of Physical Chemistry, Faculty of Engineering
Yokohama National University, Hodogaya-ku, Yokohama 240
*Mitsubishi-Kasei Institute of Life Sciences
Minamiooya, Machida, Tokyo 194
**Department of Life Science, Faculty of Science
Tokyo Institute of Technology, Nagatsuta, Yokohama 227

Origins of organic compounds on the primitive earth and in space are still controversial. We are studying the roles of cosmic rays on the abiotic formation of bioorganic compounds from plausible primitive gas mixtures. A gas mixture of carbon monoxide, nitrogen and water was irradiated by high-energy protons (major components of cosmic rays) with a Van de Graaff accelerator, and the products were analyzed. Various kinds of amino acids were detected in the products, whose chemical yield (G-value) was 0.005-0.01. Imidazole, an important molecule in prebiotic syntheses of proteins and nucleic acids, and uracil, one of the five nucleic acid bases, were also identified.

In order to investigate the effects of "natural" cosmic rays on abiotic syntheses of bioorganic compounds, utilization of polar rounding balloons is proposed. If a reaction vessel which contains a mixture of 760 Torr 1:1 mixture of carbon monoxide and nitrogen over liquid water is exposed to cosmic rays (including solar flare particles) on the polar rounding balloon (raised to 30 km high above the Antarctic bases) for 20 days, detectable amounts of amino acids are expected to be formed. For further investigations on the effects of cosmic rays on the origins of organic compounds in the primitive earth and comets, we propose utilizing a space station for longer exposure of such reaction gases with solid catalysts to cosmic rays and ultraviolet light in space.

Key words: Abiotic Synthesis, Bioorganic Compounds, Cosmic Rays, Proton Irradiation, Polar Rounding Balloon, Space Station, Origins of Life, Comets.

CAN TERRESTRIAL MICROORGANISMS SURVIVE IN COSMIC SPACE ?

Junpei KOIKE and Tairo OSHIMA

Department of Life Science, Faculty of Science,
Tokyo Institute of Technology
Nagatsuta, Yokohama, Kanagawa 227

Recently, following development of space science, many of space crafts have been launched into cosmic space. But, little of studies have been done for cosmic pollution by terrestrial microorganisms. In this studies a cosmic environment have been simulated by using ultra low temperature-high vacuum cryostat and proton irradiation from Van de Graaff. It is discussed whether some general microorganisms are able to survive in the simulated environment or not.

Key words: Cosmic pollution, Proton irradiation, Cryostat, Van de Graaff

Induction of DNA damage and mutation by solar ultraviolet light in *Escherichia coli*

Takeo OHNISHI, Kumio OKAICHI, Noriko SATO,
Sakae IWAMOTO* and Keiichi NOZU

Department of Biology, Nara Medical University, Kashihara, Nara 634 and
*Division of Food and Chemistry, Nara Prefectural Institute of Public Health,
Omori-cho, Nara city, Nara 630

In nature, organisms are constantly bombarded by visible and near-ultraviolet light (NUV) from the sun. Stratospheric ozone can reduce far-UV as a natural filter against solar UV. In space, we have many opportunities to get much more amounts of short wavelength light than on the earth. Therefore, we have investigated the biological effects of solar light on cell killing and mutation in *E. coli*. Apparent cell killing by sunlight exposure was observed in radiation sensitive mutants (*recA*$^-$, *uvrA*$^-$ and *lexA*$^-$). The expression of *umu* gene, which controls inducible mutation, was also detected to be induced by sunlight exposure in *uvrA*$^-$ cells as compared with the parental wild-type cells, but not in *lexA*$^-$ and *recA*$^-$ mutants. These results suggest that sunlight induces DNA damage repairable by excision repair and the gene expression. In addition, we measured the depression of the sunlight-induced expression of *umu* gene by various antimutagenic chemicals. 3-Aminobezamide and caffeine, which are specific inhibitors of poly(ADP-ribose) synthetase, depressed the gene expression. Similar depression was detected by vitamin C and cinnamaldehyde. Spermine but not spermidine efficiently depressed the induced activity of the gene expression. It is suggeted that the depression of the induced mutation by these antimutagens is introduced by the depression of the gene expression on *umu* gene for mutation.

Even on the earth, industrialized humans are subjected to many forms of artificial illumination that include NUV wavelengths. The "health lamp" is commonly used to promote suntanning in a room, even though NUV is known to produce DNA damage and induce skin cancer. Therefore we investigated the mutational change in base sequences in DNA molecules. A shuttle vector, pZ189, carring a bacterial suppressor tRNA marker gene, was irradiated with health lamp (HL) light (UV-B: 280-320 nm). Plasmid mutations were scored by transforming an indicator strain of *E. coli* carring a suppressive blue amber mutation in the *ß*-galactosidase gene. Plasmid survival was also measured by transforming activity of the indicator strain. The majority of mutations induced by HL light, were G·C-A·T transitions (69%) and the rest was transversion (33%). Four hot-spots in the mutations were observed within the 160-bp range sequenced. The mechanisms of the induced mutation on base-sequence specificity by HL light are discussed in relation to possible DNA damage induced by HL light.

MUTATIONS INDUCED BY LOW DOSE-RATE NEUTRONS IN *DROSOPHILA*

Mituo IKENAGA[1], Isao YOSHIKAWA[2], Toshikazu AYAKI[2], Masaharu HOSHI[3], Shozo SAWADA[3] and Kenjiro YOKORO[3]

[1]Radiation Biology Center, Kyoto University, Yoshida-konoe-cho, Sakyo-ku, Kyoto 606, [2]Nagasaki University School of Medicine, Sakamoto-cho, Nagasaki 852, and [3]Research Institute for Nuclear Medicine and Biology, Hiroshima University, Kasumi, Minami-ku, Hiroshima 734

To estimate the human risk of radiation hazards in space, we are planning to study the possible genetic effects of space radiation in *Drosophila* during the FMPT flight. As a ground control experiment, we have been analyzing for these 5 years the induction of wing hair mutations in *Drosophila* after exposure to Cf-252 neutrons and 14 MeV neutrons, in comparison to those induced by X-rays and Co-60 gamma-rays. In the previous symposium, we presented the results of mutations induced by acute irradiation; when the above radiations were delivered to *Drosophila* larvae at relatively high dose-rates (irradiation periods of less than 60 min), the induced wing hair mutations were detectable at doses as low as a few rad (cGy), and indicated that the RBE values of Cf-252 and 14 MeV neutrons were about 10 and 3, respectively.

In the present study, a long term exposure with extremely low dose-rates was employed, in order to simulate the Space Shuttle Flight lasting for about 7 days. Twenty-four hr old larvae were irradiated with Cf-252 neutrons for 120 hrs, which gave a minimum total dose of about 5 rad (cGy), and mutations were examined with wings of adult flies. The results revealed that the frequency of large spot mutations induced by the low dose-rate neutrons increased linearly with increase in total dose, and that the mutation frequency per unit dose of low dose-rate irradiation was almost the same as that induced by high dose-rate neutrons.

Key words: Mutations, *Drosophila*, Neutron, Low dose-rate

AND ITS CIRCADIAN RHYTHM

Kenichi IJIRI

Radioisotope Center, University of Tokyo,
Yayoi, Bunkyo-ku, Tokyo 113

Variations in the number of radiation-induced cell death (apoptotic cells) in the crypts in the small intestine of the mouse have been studied throughout a 24-h period under a normal light regimen (light on, 07.00-19.00 h; light off, 19.00-07.00 h). A clear circadian rhythm was displayed in the incidence of cell death 3 or 6 h after irradiation for each gamma-ray dose studied (range 0.14-9.0 Gy). The most prominent circadian rhythm was obtained after 0.5 Gy. The peak time of day for inducing cell death was 6.00-9.00 h, and the trough occurred at 18.00-21.00 h.

Some mice were also transferred to a room with the light cycle reversed and were irradiated on different days after the transfer. The transition point for reversal (i.e. the switch time from the normal-light pattern to the reversed-light pattern) of the circadian rhythm in the incidence of cell death (after 0.5 Gy) occurred 7 days after the transfer and the rhythm was reversed by 14 days.

The incidence of cell death was studied in the intestine of mice irradiated continuously for various times (3-24 h) starting at 09.00 h. Three dose-rates, i.e. 12, 30, and 60 mGy/h were employed. For each dose-rate, a steady increase in the number of cell death was noted until 9 h after the start of irradiation. Cell death then decreased till 21.00 h, although irradiation had continued. It then started to rise and steadily increased thereafter. Such time-course changes could be explained on the basis of the innate circadian rhythm of the cells susceptible to cell death mentioned above.

Key words: Circadian Rhythm, Radiation Sensitivity, Cell Death,
Small Intestine,

CHROMOSOMAL DAMAGES INDUCED BY HIGH LET AND LOW LET RADIATIONS.

Masami WATANABE, Keiji SUZUKI, Masao SUZUKI,
Kazushiro NAKANO*) and Ichiro KANEKO*)

Division of Radiation Biology, School of Medicine,
Yokohama City University, Yokohama 236
and
*)RIKEN, Wako 351

We compared the qualitative and quantitative differences in chromosome damages induced by low and high LET radiations. The induction of chromosome aberrations ,such as chromatid breaks and exchanges, were examined in golden hamster embryo cells . The number of aberrations per cell increased as increasing doses. As compared with X-rays, the frequency of aberration in population irradiated by He-ions (36 keV/um) was slightly decreased. On the other hand, the induction of chromosome damage by N-ions (530 keV/um) was much lower than that by He-ions. The relative numbers for breaks at 50% survival level was 0.5 in cells irradiated by He-ions and 0.2 by N-ions. In order to determine the chromosome aberrations associated with neoplastic transformation, we isolated morphologically transformed clones and analyzed their karyotypes. Although total chromosome numbers were same as normal embryo cells, all 7 clones isolated had structural changes. All clones also acquired tumorigenicity. These results suggested that chromosomal damages induced by high LET radiations might be different from those of low LET radiations both in their number and in their quality.

Key word: High LET radiations, golden hamster embryo cells, chromosome aberration, neoplastic transformation.

BEHAVIOR OF CELLS DURING CENTRIFUGATION AS REVEALED BY THE VIDEO CENTRIFUGE MICROSCOPE

Kiyoko KURODA and Noburô KAMIYA

Department of Biology, Faculty of Science
Osaka University, Toyonaka, Osaka 560

To observe and analyze the behavior of cells under centrifugal acceleration, we constructed two centrifuge microscopes of a new type(1,2). The rotor of the apparatus housed the entire microscope optics, the remotely controllable stage for loading a microcuvette containing a specimen, the CCD video camera and the transmitter. The image information from the video camera was received wirelessly by the stationary antenna(3), displayed on the video monitor and recorded with VTR. Here we report the behavior of two entirely different types of cells during centrifugation, the young internodal cell of Nitella axilliformis and Paramecium caudatum(2,3).

Nitella. At 250xg, most of the flowing endoplasm collected at the centrifugal end of the cell. By decreasing centrifugal acceleration to 110xg, a clearly recognizable streaming was started as a thin layer against the centrifugal force. When centrifugation stopped, normal streaming soon resumed. The process was perfectly reversible. The streaming velocity-centrifugal force relation was not linear, which was explained by the thinning of the endoplasmic layer during centrifugation. Changes in streaming velocity induced by moderate centrifugal acceleration enabled us, through extrapolation to zero velocity, to estimate the motive force responsible for the streaming. It was calculated to be about 1 dyn cm^{-2}, corresponding well with the data obtained by other methods(4,5,6). It was noted that the increase in streaming in the centrifugal direction was less than the decrease in the centripetal direction.

Paramecium. In a graded density medium, Paramecium cells were oriented by centrifugation at (300-400)xg with their long axes in parallel with the radial direction of the centrifuge. Our experiment(2) indicated that 87.5% of all paramecia in the early stationary phase when they show clear negative gravitaxis, pointed upward and only 12.5% downward, while those in the late stationary phase when the ciliates show no negative gravitaxis, the ratio of upward and downwa d-directed ones was 45.4 : 54.6. If the center of gravity and center of buoyancy of the cell were the same before centrifugation, the ratio of upward-directed and downward-directed cells under centrifugal force should be 1 : 1, since it may be simply a matter of chance which end of the cell comes to the top. However, if the center of gravity of the cell is located posterior to the center of buoyancy under 1xg, there will be a higher probability for the cell to point upward in the field of centrifugal acceleration. The present study indicates, supporting the old Verworn hypothesis(7), that the center of gravity of Paramecium caudatum is indeed posterior to the center of buoyancy when the cell exhibits negative gravitaxis.

Since all of the paramecia still retained their active swimming capacity under (300-400)xg, they did not stay quietly at their isopycnotic level. It was possible to calculate their propulsive force from the difference between their density and that of the upper or lower layer which they could reach. The propulsive force of a single Paramecium cell was calculated to be about 7×10^{-4} dyn(3).

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Key words: video centrifuge microscope, cytoplasmic streaming, Nitella, Paramecium, gravitaxis, propulsive force

A SPACE-BIOLOGICAL STUDY OF GRAVITY RECEPTION
—MEASUREMENT OF INTRACELLULAR FREE CALCIUM CONCENTRATION—

Akira MURAKAMI[1], Masamichi YAMASHITA[2], Naokata ISHII[1], and Yukihisa HAMAGUCHI[3]

[1] Zoological Institute, Faculty of Science, University of Tokyo, Bunkyo-ku, Tokyo 113
[2] Institute of Space and Astronautical Science, Sagamihara, Kanagawa 229
[3] Biological Laboratory, Tokyo Institute of Technology, Meguro-ku, Tokyo 152

Statocycts in various organisms are gravity receptors in which a mineralized concretion, statolith or otolith, stimulates the hair cells mechanically. Recent studies have indicated that an influx of calcium ions into the hair cells is an important process in the sensory transduction. On the other hand, organisms such as *Paramecium* and sea urchin embryos show gravitactic responses without any obvious statocyst-like structures. *Paramecium* is highly sensitive to mechanical stumuli and the response is calcium dependent. Using *Paremecium*, we are investigating the effect of microgravity on the cellular activities, especially by measuring the intracellular free calcium ion concentration, and are developing a dual-excitation fluorescence assay system using the calcium indicator fura 2. The excitation maximum of fura 2 is shifted towards a shorter wavelength as the calcium concentration of the medium is increased. Thus, the ratio between the fluorescence intensities that is excited by wavelengths of 340 nm and 380 nm and measured at 510 nm is used as a reliable measure of the intracellular free calcium ion concentration. *Paramecium* was loaded with 1 μM fura 2/AM in the presence of 0.05 % Pluronic F-127 for 3-6 hrs at 30°C. Under a fluorescent microscope, the fluorescence excited at 340 nm was observed in the cytoplasmic matrix as well as in many vacuoles and granules. On the other hand, *Paramecium* which was loaded with fura 2/AM in the absence of Pluronic F-127 showed no fluorescence in the cytoplasmic matrix, although many granules and vesicles in the cytoplasm showed considerable fluorescece. Fura 2 loaded *Paramecium* swam with a velocity comparable to that of the unloaded organism, indicating that the 3-6 hr loading does not seriously affect the normal activities of the organism. The intracellular level of free calcium ions was about 80 μM and markedly increased by an addition of 50 μM digitonin to the medium. The results suggest that fura 2 can be used to monitor the intracellular free calcium ion concentration in *Paramecium* and other cells in space experiments.

Key wards: Microgravity, Fura 2, Ca, *Paramecium*

ANALYSIS USING GRAVITY AS AN EXPERIMENTAL VARIABLE

Mayumi OOYA, Shoji A. Baba, Yoshihiro MOGAMI

Department of Biology, Ochanomizu University
Otsuka, Tokyo 112

Akemi IZUMI-KUROTANI, Masamichi YAMASHITA

Institute of Space and Astronautical Science
Sagamihara, Kanagawa 229

Makoto OKUNO
Department of Biology, University of Tokyo
Komaba, Tokyo 153

Negative geotaxis or preferentially upward swimming may be one of strategies for preventing the body from sinking in the gravity field of the earth in microorganisms that are heavier than the surrounding water. An alternative way to keep the body from sinking is steady or spontaneous alteration of the direction of swimming and regulation of its speed depending on the direction, increasing propulsion when swimming upward and decreasing it when swimming downward. This second way may be helpful for animals to stay in midwater as if they were neutral in buoyancy, adapting to the gravity field of the earth.

We recorded the swimming of *Paramecium caudatus* under hypergravity (centrifuge experiments). The observed velocity was compared with the equation, $v = \sqrt{(p^2 - s^2\sin^2\theta)} + s\cos\theta$, where s is sinking speed and p propulsion. Paramecia that swam along straight paths obeyed this equation at least up to 3 G, when s was evaluated from free falling cells and p was assumed to be constant, whereas paramecia that swam along curved paths seemed to violate this equation by keeping v rather constant in all directions.

However, straight swimmers deviated the theoretical prediction over 4 G, suggesting some regulation of the propulsion. For straight swimmers, the difference of downward velocity and upward velocity divided by 2, which will be referred to as Vd, increased with increasing gravity and was nearly equal to the sinking speed up to 3 G but dropped over the critical G, indicating onset of regulation depending on the gravity. For curved swimmers, similar drop in Vd was also observed over 4G, suggesting gravity-dependent regulation of propulsion. These facts may strongly suggest gravireception in *Paramecium*.

Key words: Gravireception, Hypergravity centrifuge, *Paramecium*

EFFECT OF GRAVITY ON SHOOT GROWTH IN HIGHER PLANTS

Seiichiro KAMISAKA[1], Kazuhiko NISHITANI[2], Takayuki HOSON[1], and Yoshio MASUDA[1]

1 Department of Biology, Faculty of Science, Osaka City University
Sumiyoshi-ku Osaka 558, Japan

2 Biological Laboratories, Liberal Arts College, Kagoshima University
Kagoshima 890, Japan

Water immersion method was applied to the analysis of the effect of body-weight reduction on growth and physicochemical properties of the cell wall in rice coleoptiles (Oryza sativa L. cv. Nihonbare). Germinated seedlings were grown at 25°C in the dark under three different conditions (under 10 cm depth of water, under water with air bubbling, and in air). Coleoptile growth was larger under water without bubbling than in air. Air bubbling suppressed coleoptile growth, but the suppression was incomplete. Cell wall extensibility was larger in water-type coleoptiles than in air-type or bubbling-type ones. Water immersion decreased the content of matrix polysaccharides, cellulose, and diferulic acid ester-linked to matrix polysaccharides in the cell wall. The content of these substances in the cell wall was smaller in bubbling-type coleoptiles than in air-type ones, indicating that the construction of rigid cell walls is suppressed under water. These facts suggest that in addition to oxygen concentration, a decrease in body weight under water due to buoyancy stimulates coleoptile growth by affecting physicochemical properties of the cell wall.

Key words: Air bubbling, Buoyancy, Cell wall, Cell wall extensibility, Cellulose, Coleoptile, Diferulic acid, Growth, Matrix polysaccharides, Oryza sativa L., Rice, Water immersion.

GROWTH RESPONSE OF HIGHER PLANTS IN A SIMULATED WEIGHTLESS ENVIRONMENT

Takayuki HOSON[1], Seiichiro KAMISAKA[1,2], Yoshio MASUDA[1], and Masamichi YAMASHITA[2]

[1] Department of Biology, Faculty of Science, Osaka City University, Sugimoto, Sumiyoshi-ku, Osaka 558
[2] Institute of Space and Astronautical Science, Yoshinodai, Sagamihara, Kanagawa 229

3-D Clinostat is a useful experimental tool to simulate a weightless environment on the ground. In order to clarify the role of gravity in regulation of vegetative growth processes of higher plants, we investigated the effect of 3-D clinostat rotation on germination, elongation growth, morphogenesis, and gravitropism in some species.

3-D Clinostat rotation did not influence germination of cress (Lepidium sativum L.) and rice (Oryza sativa L.) seeds. There was no difference in length of hypocotyls, coleoptiles, or roots between clinostated cress, rice, or maize (Zea mays L.) seedlings and controls. Elongation of maize roots was slightly suppressed by a magnetic field of 3000 gauss. This suppression of elongation was also observed on a 3-D clinostat. Thus, germination and early stage of vegetative growth of plants may progress normally in a simulated weightless condition, as in space environments.

The orientation of shoots and roots is determined spontaneously under microgravity. Under 1-g condition, germinated radicles of cress bend toward the ground by a positive gravitropism and grow parallel to the gravity vector. On a 3-D clinostat, germinated radicles curved spontaneously and maintained the arc shape for a couple of hours. The arc was opened gradually during the following growth period. At about 30 h after germination, the roots formed a straight line from the tip of embryonic radicle, as observed in a space flight. Roots of maize did not show the gravitropic response on a 3-D clinostat. However, some roots performed spontaneous irregular curvatures. The spontaneous orientation (automorphogenesis) and the spontaneous curvature (autotropism) of plant organs were detected more clearly on a 3-D clinostat than on a conventional horizontal clinostat.

The results obtained in the present study indicate that germination or growth rate of plants is not while morphogenesis or tropism is affected by weightlessness produced by 3-D clinostat. The ground-based experiments using this clinostat in combination with the appropriate flight experiments will further clarify the role of gravity in regulation of vegetative growth processes of higher plants.

Key words: Automorphogenesis, Autotropism, 3-D Clinostat, Germination, Gravitropism, Growth, Higher Plants, Lepidium sativum, Microgravity, Morphogenesis, Oryza sativa, Vegetative Growth, Weightlessness, Zea mays.

PLANT PHOTOSYNTHESIS IN COSMIC ENVIRONMENTS

Kozi ASADA

The Research Institute for Food Science
Kyoto University, Uji, Kyoto 611, JAPAN

In cosmic environments plants would be exposed to ultraviolet light and radiation at high intensity compared with those on the earth, and the interaction of these raditions with cells causes higher rates of production of active oxygen (superoxide, hydrogen peroxide, hydroxyl radical and singlet excited dioxygen). Thus, for the growth in cosmic environments, the plants should have a high capacity of protection against the photooxidative damages due to the oxidation of cellular components by active oxygen.

The protection mechanisms against photooxidative damages of plants are divided, at least, to four. One of them is the suppression of the production of active molecules including active oxygen. It includes genetic, physiological, biochemical and biosynthetic mechanisms, and all of them, independently or cooperatively, participates in the suppression of the production of active molecules under various conditions.

Even so the production of active molecules is suppressed, but, it is inevitable and cannot make zero. Because even the small amounts of active molecules escaped from the suppression mechanisms cause the photooxidative damages, the scavenging of active molecules is essential to the plant growth. Active molecules are scavenged by enzymes and low molecular weight antioxidants. The scavenging enzymes are superoxide dismutase, catalase, peroxidases and related enzymes, and so many antioxidants have been found in plants.

In addition to the suppression and scavenging mechanims of active molecules, plants are protected from photooxidative damages by the repairing and de novo synthesis of target molecules damaged with active oxygen. A high capacity of these four mechanisms for the protection from photooxidative damages are induced to plants under the environmental stresses which cause the high production rate of active molecules. However, the molecular mechanisms for the induction have still remained unsolved. For the molecular breeding of plants which are able to grow in cosmic environments, understanding of molecular mechanisms of the suppression and scavenging of active molecules, the repairing and de novo synthesis of target molecules and of their induction mechanisms is required.

PHOTOTROPIC RESPONSE IN GRAVITY-COMPENSATED AVENA COLEOPTILES

Yasuhiro MIYOSHI and Yuji MORIYASU

Department of Biology, University of Shizuoka, 395 Yada,
Shizuoka 422, Japan

In order to study phototropism without the effect of geotropism, we made a clinostat which is composed of 5 growth chambers rotating at 2 rpm, a monochromatic light pulse irradiator and a TV camera system to monitor the temporal changes of bending. The monochromatic light pulse irradiator is consisted of 5 partially transmitting mirrors and a shutter synchronized with the rotation of the growth chambers. It can thus project 5 pulse beams of different intensity on the same side of the 5 growth chambers once a rotation. Apparent gravity along the longitudinal axis of Avena coleoptiles can be changed from 0G to 1G by tilt of the axes of rotation of the growth chambers from horizontal. Using this apparatus, we measured the time-courses and fluence-response curves of first positive phototropism to blue light (450nm) in red light grown Avena coleoptiles under apparent 0G and some apparent Gs below 1G.

Key words:phototropism, clinostat, the time-course, fluence-response curve, Avena

MANUFACTURING AND EVALUATION FOR A TRIAL MODEL OF SPACE BIOLOGY EXPERIMENT ONBOARD SFU-1

Yuichi MURASE[1], Satoru KOMADA[1]
Makoto ASAJIMA[2]
Masamiti YAMASITA[3], Akemi KUROTANI[3]

[1]Fujitsu Laboratries Ltd., Kawasaki, Kanagawa 211
[2]Department of Biology, Yokohama City University, Yokohama, Kanagawa
[3]Institute of Space and Astoronautical Sience, Sagamihara, Kanagawa

We are developing a system to do a space biology experiment onboard SFU-1. There are two adult newts in this system. By Observing their eggs, we can research the effects of microgravity. From prelaunch to expriment start, the newts are kept in hibernation by keeping the water at 4℃. To start the experiment, the water is heated to 22℃ to make the newts active. And they lay eggs with hormones. So, the system is required to supply oxygen, to control the water temparature, to observe the eggs, and to fix them in order to stop the developement and privent decay. In this paper, we have evaluated these functions on a trial model. The model has a weight of 12.3 kg, a height of 312 mm, and a diamater of ϕ 296 mm. The oxygen supply capability is 1.6ml/h. Water temparature can be controled at 7.9 ℃ on earth. In space, it can be done clearlybecause the system will be insulated better to privent convection losses. The system has a mechanism to observe the eggs two dimensionally. So we can obtain a picture showing the cell division state. The time needed to diffuse the fixative reagent is about 6 minutes.

Key Words: Space biology experiment, SFU, Closed life support system, Development of newt's eggs

Micro-manipulation of Single Cells and Bio-Molecules Using Electrostatic Force and Optical Pressure Under Low Gravity

Akira Mizuno and Masao Washizu*

Dep. of Electrical and Electronic Engineering.
Toyohashi University of Technology. Toyohashi. 440. Japan.
*Dep. of Electrical Engineering. Seikei University
Kichijoji-kitamachi. Musashino-shi. Tokyo. 180. Japan.

Mirco-manipulation of single cells or bio-molecules may be one of key technologies for not only handling. separation and measurement of cells and monlecules. but also for fabrication of bio-molecular devices. The authors have developed the "Fluid Integrated Circuit" fabricated using photolithography. where micro-electrodes and micro-passages for cells are integarated onto one substrate. Manipulations of individual cell is realized by the electrostatic force under very high intensity field which is produced between micrometer-sized narrow gap in the FIC. Electrolysis can be eliminated using a high frequency ac voltage. The authors have develped plant manipulation system based on FIC. including a plant-cell fusion device where one-to-one cell fusion among different speces is realized. DNA molecules can also be manipulated in FIC. Single DNA strings can be aligned under high electric field.

The authors have also developed the "Opt-Electrostatic Micro-Manipulation". utilizing the electrostatic force in combination with the optical pressure of focused laser beam. The optical pressure has two components. the optical confinement pressure and the optical drift pressure. Due to the optical confinement pressure. cells can be confined in the focused laser beam. The confined cells are pushed away toward downstream of the laser beam. The combination of the optical pressure and the electrical force can be made using a micro-electrode system having an insulating slit. The cells can be manipulated on the beam axis by the balance of the electrostatic force and the optical drift pressure. The laser beam determines the path of the cells on which the electric field strength can be calculated. Therefore. the electrical force to the cells can also be calculated and an accurate manipulation can be achieved. It is noted that very fine defraction pattern of the confined cell can be obtained. This enables an accurate measurement of the cell configuration. The opt-electrostatic micro-manipulation can be applied to handle chromosones or larger bio-molecules of more than about 20 nm diameter.

In these micro-manipulations. convection flow occurs due to Joule loss and absorption of laser beam. and deteriorates the accuracy of the manipulation. Under the low gravity condition. the convection flow can greatly be eliminated. so that an accurte and high speed micro-manipulation can be conducted.

key words

micro-manipulation. micro-fabrication. biological cells. bio-molecules. electrostatic field. optical pressure. opt-electrostatic micro-manipulation. fluid integrated circuit. low gravity

EFFECTS OF AGING ON THE ATROPHY AND CONTRACTILE PROPERTIES OF TENOTOMIZED GASTROCNEMIUS MUSCLE IN RAT

Y. OHIRA, N. NAKAJIMA, H. TAKEKURA, N. INOUE, and K. SAITO

Department of Physiology and Biomechanics
National Institute of Fitness and Sports, Kanoya City, Kagoshima 891-23

The mechanism of the muscle atrophy induced following space flight or unloading in rat hindlimbs is still unclear, even though it is obvious that the reduced contractile activity has the major effect. Effects of aging on the changes in muscle mass and contractile properties of rat gastrocnemius in response to tenotomy were investigated in the current study. The major finding was that although the degree of muscle atrophy was greater in young rats, significant changes in speed-related contractile properties were observed only in old rats. The old intact gastrocnemius was slower than young muscle. These results may indicate that slow-type fibers are more susceptible to tenotomy and contractile properties of whole muscle are shifted toward fast-type. The greater atrophy in young muscle may be caused by their higher turnover rate and less parameters such as connective tissues which may not be affected by tenotomy.

Key words: Rat gastrocnemius, Tenotomy, Atrophy, Contractile properties, Aging

Mitochondria and lipid droplet volume of suspended-skeletal muscle

Toshitada YOSHIOKA* Hiroaki TAKEKURA** Midori TANAKA*
Katsumasa YAMASHITA* and Yoshinobu OHIRA**

*Department of Physiology, St. Marianna University
School of Medicine
(2-16-1 Sugao, Miyamae, Kawasaki, Kanagawa 213, Japan)

**Department of Physiology and Biomechanics,
National Institute of Fitness and Sports
(1 Shiromizu, Kanoya, Kagoshima 891-23, Japan)

Abstract

The alterations in structural and biochemical properties in the slow and fast skeletal muscles and in three types of muscle fibers of rats during body suspension hypokinesia were investigated. Degenerative features, such as myofibrillar disruption and compression of myofibrils by extracellular enlarged spaces, were observed in suspended- and stimulated-muscle. The mitochondrial volume of SO (slow-twitch oxidative) fiber from suspended-muscle, revealed by a pointcounting method, was similar to that of control FOG (fast-twitch oxidative and glycolytic) fiber. The mitochondrial volume from stimulated-FG (fast-twitch glycolytic) fiber recovered to the control FG level. The volume of lipid droplets, which was significantly elevated by suspension, was markedly decreased after electrical stimulation.

These results identify specific alterations with some degree of reversibility on muscles according to the types of skeletal muscle and muscle fiber.

Key words: Suspension hypokinesia, Muscle fiber type, Electrical stimulation, Mitochondria, Lipid droplet

MECHANISN OF ANTIGRAVITATIONAL MUSCLE ATROPHY

-SPECIFIC PROTEIN COMPONENT DECREASED IN ATROPHIED SOLEUS WITH RAT TAIL-SUSPENSION MODEL-

Yoriko ATOMI, Shigeru YAMADA, Hideo HATTA, Yoriko YAMAMOTO* and Shigeko SHINOHARA**

University of Tokyo, College of Arts and Sciences, Dept. of Sports Sciences, Komaba, Meguro-ku, Tokyo Japan 153, *Sagami Women's Univ. **Keio Univ.

Rat hindlimb suspension results in muscle atrophy, particularly in the slow-twitch soleus, antigravitational muscle, but the molecular mechanism is poorly understood. We have found the specific protein component in soleus muscle by SDS-PAGE referred to as 22-kDa protein. We have reported the chemical characteristics of this protein in last year. In order to know whether this protein is new or a known protein, this protein was purified and the amino-acid sequence was determined. Since N-terminal was blocked, one of peptides fractionated by lysilendopeptidase was analyzed. As a results, 22-kDa protein was similar to B chain of γ-crystalline, which was expressed in lenze of eyes. The accordanse between 22-kDa protein and bovine αB-crystalline was ascertained from peptide mapping with HPLC using lysilendopeptidase, amino acid composition and immunological responsibility. Further investigation is needed to find the function of 22-kDa protein in soleus muscle cells.

A CHARACTERISTIC CHANGE OF HIP FLEXOR MUSCLES ACTIVITIES DURING ISOMETRIC CONTRACTION BY WATER IMMERSION.

Genyo MITARAI, Yasuhiro SUGAJIMA, Mitsuhiro KOEDA and Toshio MORITANI*

Laboratory of Exercise Physiology, Faculty of Physical Education, Chukyo University, Toyota, Aichi 470-03

*Human Performance Laboratory, Hoken-taiku, Kyoto university, Sakyo-ku, Kyoto 606

It is assumed that relation of muscles under weightlessness may result in some changes of muscular synergy in joint movement. The present study aimed to examine this hypothesis by analyzing the mode of synergy in flexor muscle groups during voluntary isometric contraction under water immersion. The subjects were 16 healthy 21-26 aged males. They kept upright standing in water, being lightly flexed the body on an appropriately equipped Then, subjects performed an isometric hip joint flexion of right leg with a constant angle of 120 degrees, against to four different contraction forces. During each performance, electromyograms (EMGs) were obtained from Iiopsoas(ILIOP), tensor fasciae latae (TFL), sartorius(SART) and rectus femoris(RF). The the same recordings were obtained without water immersion as the control. Under water immersion, the EMG discharges of all muscles lowered comparing with those under dry conditions, and the proportion the EMG discharges among the four muscles was different both conditions. The SART EMG became larger in proportion under water immersion than in dry conditions, while the TFL EMG became smaller. It was also found that the motor units of ILIOP and SART produced frequently large transient spikes under water immersion. The results obtained suggested that the synergetic activity of muscle groups and the contraction property of each muscle are changed by weightlessness.

Key Words: Water Immersion, Hip Joint Flexion, Motor Unit, Muscular Cooperation

Involvement of Corticosterone and Testosterone in Muscle Atrophy of Rats induced by Tail Suspension

Kaori SUEDA*, Norihiro MIYAMOTO, Yoshio NOMURA,
Hisao SEO and Nobuo MATSUI

*Nagoya Women's University ,Mizuho-ku, Nagoya 467
The Research Institute of Environmental Medicine,
Nagoya University, Chikusa-ku, Nagoya 464-01

Involvement of corticosterone and testosterone in muscle atrophy of rat hindlimbs was investigated in a tail suspension model. Male Wistar rats of 5-week-old were decapitated after 7-day suspension. Wet weights of the adrenal, the testis , the thymus and the muscles were measured. The levels of serum corticosterone and testosterone were determined.

Body weight gain of the suspended rats was about one third of that of control rats. The weights of soleus, gastrocnemius and extensor digitorium longus muscle were significantly decreased in the suspended rats. The relative weight of the soleus and gastrocnemius to body weight just before decapitation were also decreased in the suspended rats.

The adrenal was hypertrophied by suspension. The thymus weight was smaller in suspended rats, suggesting sustained exposure to a high concentration of corticosterone. The level of serum corticosterone was high in both groups, probably because of stress at the time of decapitation. The testis was atrophied by suspension and the level of serum testosterone was lower in the suspended rats.

The soleus weight tended to be negatively correlated with the adrenal weight while positively correlated with the testicular weight. These results suggest that the both corticosterone and testosterone are involved in muscle atrophy of rat hindlimb induced by tail suspension.

Key words: tail suspension, muscle atrophy, corticosterone, testosterone

INVESTIGATION OF EYE MOVEMENT DURING THE PARALLEL SWING BEFORE AND AFTER THE ABLATION OF OTOLITHIC MEMBRANE OF MONKEY AND GUINEA PIG

Takashi FUTAKI and Taeko OKUNO

Department of Otolaryngology, University of Tokyo Hospital
Hongo, Tokyo 113

Recording of the sinusoidal eye movement during the parallel swing can be obtained in monkey and guinea pig.

This otolithic response is considered to be much important for estimation of otolithic behavior in the situation of microgravity. Utilizing the microscope with laser beam gun, we could make the selective ablation of the otolithic reaction before and after the destruction. the histologic findings were also demonstrated.

DORSAL LIGHT RESPONSE OF LITHOTOMIZED GOLDFISH RESPONDED BY ROTATORY ILLUMINATION STIMULATION

Satoru WATANABE and Sadaharu TAKAGI

Research Institute of Environmental Medicine, Nagoya University
Furocho, Chikusa-ku, Nagoya 464-01

The body equilibrium of fish is mainly controlled by visual and static stimuli. Both stimuli act on detection of the vertical. Visual stimuli are generally able to be given even from various directions. The dorsal light response of fish is just suitable to examine the relationship between static and visual contribution for adjusting the posture. In this experiment, we used a rotatory illumination device for the visual stimulation, which was constructed a rotating illumination drum outside and cylindrical fish container inside. Thus, the rotatory illumination device enable to survey the dynamic response of the DLR. Tilting reaction of goldfish to the rotatory illumination stimulation needed to some degrees of light intensity difference between both eyes, which was produced by inclination of illumination to the fish. Tilting response started firstly at 40° of the inclination angle and became maximum at 120°. This was also proved by the illumination intensity change experiment, which showed that the weaker the intensity, the larger the inclination angle of illumination. This behavior is explainable as the tonus asymmetry produced by the difference of visual inputs of both eyes.

The bilateral lithotomized goldfish responded almost perfectly to turn their dorsal surface to the illumination direction. The unilateral lithotomized goldfish showed that if illuminated from intact side, they responded like as the intact fish and if illuminated from operated side, they responded like as the lithotomized fish. This indicates that the visual information from each eye is carried all crossing to each opposite brain half, where the information is integrated with the static information.

Key words: Dorsal Light Response, Goldfish, Lithotomy, Rotatory Illumination Stimulation, Tonus Asymmetry.

CHANGES IN VENOUS PRESSURE GRADIENTS ALONG THE VENA CAVA DURING POSTURE CHANGE IN ANESTHETIZED CATS

Nobuyuki TERADA, Jouji HORIUCHI, Mitushiro NAGAO and Toru TAKEUCHI

Department of Physiology, Yamanashi Medical College,
Tamaho, Nakakoma, Yamanashi 409-38

Effects of hydrostatic load on venous pressure gradients along the vena cava from the superior to inferior during posture change were studied in anesthetized cats. The venous pressure was measured with 4 Fr. transducer-tipped catheter (Camino Laboratories). Head down tilt (30°) caused the following venous pressure changes: the pressure in the superior vena cava at the origin of the internal thoracic vein significantly rose to 1.9 ± 0.21 mmHg (mean ± SE, n=6) from -0.1 ± 0.31 mmHg; the pressure at the right atrium did not change significantly; the intra-thoracic inferior vena cava pressure significantly fell; the pressure of the inferior vena cava at the caudal side of the diaphragm significantly rose to 5.5 ± 0.25 mmHg from 2.9 ± 0.40 mmHg; the pressure of the inferior vena cava around the origin of the renal vein did not change; the inferior vena cava pressure gradually decreased as the position measured going to caudally. During the 30° head up tilt, the pressures in the superior vena cava and the right atrium significantly decreased. The inferior vena cava pressure during the tilt gradually rose as the position measured going to caudally.

These results suggest that the diaphragm may have a valvular function which protects the heart from overload caused by the head down tilt.

Key words: Venous Pressure Gradients, Head Down Tilt, Head Up Tilt, Diaphragm

ANP AND DISTURBANCE OF BODY FLUID REGULATION UNDER MICROGRAVITY

Taketoshi MORIMOTO, Eizo SUGIMOTO and Munetaka HIROSE

Kyoto Prefectural University of Medicine
Kamigyoku, Kyoto 602

The body fluid shift from the lower limbs toward the head that occurs during spaceflight causes various disturbances in body fluid regulation including swelling of face. The swelling of face can not be explained only with the redistribution of blood to face, and the mechanism which causes fluid shift from intravascular to extravascular space should be clarified. Recently, increase in ANP consequent to head out water immersion has been reported, and there is a possibility that ANP is involved in the fluid shift. Thus, the effect of ANP on capillary permeability was tested in this experiment.

The nephrectomized, anesthetized rats were infused with saline (control; n=7) or saline with 1 nmol/100 g body wt of rANP(ANP group; n=7). The infused volume of saline was 1.6% of body wt in 10 min, and the changes in blood volume(BV), mean arterial pressure(MAP) and central venous pressure(CVP) were determined continuously during the 10 min of infusion and 40 min of recovery. In the ANP group, increases in BV were not as great, and recovery was threefold faster than that of the control group. In the ANP group, the recovery time of BV to the starting control levels was 8.5 min, and the time constant of recovery was 3.6 min^{-1}. The control group times were 25 min and 11.5 min^{-1}, respectively. The effective vascular compliances were about 2.8 $ml \cdot mmHg^{-1} \cdot kg$ body wt^{-1} in both groups, and the capillary filtration coefficient was 0.47 $ml \cdot mmHg^{-1} \cdot min^{-1} \cdot kg$ body wt^{-1} in the ANP group and 0.33 $ml \cdot mmHg^{-1} \cdot min^{-1} \cdot kg$ body wt^{-1} in the control group. Thus the whole body capillary filtration coefficient was 1.5-fold higher in the ANP group than in the control group. This suggests that ANP may increase the permeability of capillaries and causes swelling of face under microgravity.

Key words: Face swelling, ANP, Capillary permeability

Effect of Simulated Weightlessness on Vitamin A Status in rats

Sachiko TAKASE, Toshinao GODA, Hidehiko YOKOGOSHI
and Takeshi HOSHI

School of Food and Nutrional Sciences
University of Shizuoka
Yada, Shizuoka-city, Shizuoka 422

Changes in various types of nutritional metabolism may be resulted from hormonal changes associated with weightlessness, stresses and unknown factors during the space flight. According to the report, the urinary androsterone demonstrated a 50 % decrease after space flight. The low testosterone level in serum was found with vitamin A deficient rats. The deficient animals exhibit tescular atrophy and loss of the germinal epithelium. Those informations suggest that weightlessness and stresses might cause changes in vitamin A status. We attempted to examine effects of simulated weightlessness on vitamin A status of rats.

To make simulated weightlessness condition, a rat wearing a special jacket was suspended by hanging up metal chains which fixed to the jacket tightly, to the four corner of a wire cage. Wistar-strain male rats were housed for 10 days under the condition of the suspension.

Experiment I: Animals of one group were suspended for the simulated weightlessness experiment. Other group for normal rats received a commercial stock diet ad libitum. The other group for control rats was pair-fed in reference to the suspended group, as the food intake of the suspended group decreased approximately 40 percent. Serum retinol level of the suspended rats significantly decreased compared to the control group. In lungs and testis, retinyl palmitate contents of lift-up rats were declined in response to the simulated weightlessness, but retinol levels were not greatly altered by the suspension. The extent of the decrease of retinyl palmitate level was larger in the testis than that in the lungs.

Experiment II: It was examined to clarify as to whether dietary protein levels might affect vitamin A status of the suspended rats. Rats were fed ad libitum on the diets containing various levels of casein (5, 10, 20, 40 and 60%) for 10 days. The testicular retinyl palmitate levels of the suspended rats were not altered by the various levels of dietary protein. The values of the contents were approximately identical among the 5 groups feeding the various protein levels. Hepatic retinyl palmitate also showed the same levels among the 5 groups. These hepatic levels of retinyl palmitate were remarkably higher than that of the control group.

Experiment III: Rats for the experimental and control groups were force-fed the same amounts of diet as that fed by the normal rat group. The changes in retinol and retinyl palmitate levels in serum, lungs, testis and liver of the suspended rats were similar to those found in the experiment I and II. In spite of receiving the sufficient nutrients from the force-feeding, the suspended rats showed remarkable changes in the vitamin A status.

The most significant result obtained from this study was that hepatic retinyl palmitate was elevated by the simulated weightlessness with hanging rats. This result suggest that the simulated weightlessness or stresses associated to the suspension of rats would prevent secretion of retinol from rat liver.

Key words: Simulated weightlessness, Suspension, Vitamin A status

Fluid Metabolism Immediately After Exposure to Weightlessness --- Potentiation of Atrial Natriuretic Polypeptide Action by Glucocorticoid

Hisao SEO, Kazumi KANDA, Yoshiharu MURATA, Itaru INOUE, Norihiro MIYAMOTO, Kaori SUEDA, Sachiko OHMORI, Nobuo MATSUI

The Research Institute of Environmental Medicine, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-01

Exposure to 0G weightlessness from 1G environment results in cephalad fluid shift. It is suggested that the rise in central venous pressure caused by this cephalad fluid shift inhibits the secretion of antidiuretic hormone (ADH)[Gauer's reflex]. However, it has been shown that ADH levels determined in the actual space was not suppressed but often elevated. Thus, the increased urine flow observed immediately after exposure to weightlessness may be caused not by the inhibition of ADH secretion but by other mechanism(s).

We postulated that atrial natriuretic polypeptide (ANP) could be involved in the diuresis. Indeed, in the experiment with simulated weightlessness by water immersion revealed that cephalad fluid shift is associated with the increased secretion of ANP. Cortisol secretion was shown to be decreased by water immersion. However, in actual space flight, cortisol secretion was also increased as was ADH. Thus, it is possible that increased cortisol level could influence the action of hormones related to fluid metabolism. This possibility was tested by utilyzing the cultured rat renal cells in vitro.

When the effect of steroid hormones ANP-stimulated cyclic GMP formation was studied in renal cells, it was revealed that dexamethasone increased ANP-stimulated cGMP frosation in a dose dependent manner. Cortisol, corticosterone and aldosterone at a concentration of 10^{-7} M also potentiated ANP-stimulated cGMP formation, although triiodothyronine, oestradiol and testosterone were ineffective. Thus, potentiation of ANP action by these steroid seems to parallel glucocorticoid activity. Glucocorticoid did not affect the ADH-stimulated cAMP formation.

In summary, increased cortisol level observed in the space flight mayt potentiate ANP action, resulting in diuresis even in the presence of ielevated ADH levels.

SWEATING RESPONSES TO VARIOUS POSTURAL CHANGES

Tokuo OGAWA and Keiko NATSUME

Department of Physiology, Aichi Medical University
Nagakute, Aichi 480-11

As a part of investigation of thermoregulatory function in weightlessness, effects of various postural changes, such as lifting of unilateral upper or lower limb, lifting of bilateral lower limbs, and body tilting between +15° and -15°, and between +90° and -6°, on sweating activity were examined. Sweat rate on areas of the lifted limb decreased markedly during passive elevation of a unilateral upper or lower limb, whereas active elevation induced a less decrease in the local sweat rate. Changes in the local sweat rate appeared to parallel those in the local skin blood flow. Arterial occlusion and congestion of the upper limb caused a decrease in the local sweat rate similarly to passive limb elevation. The rate of drug-induced sweating was hardly affected by limb elevation, decreased during arterial occlusion, and increased by congestion. These observations suggest that regional sweating activity is affected considerably by blood supply: oxygen supply is required for the release of transmitter at the neuroglandular junction but not for sweat-secretory activity of the gland, for which water supply is prerequisite. The results also suggest that the reduction of sweat rate of the lifted limb is mainly induced by reduced transmitter release due to hypoxia. On the other hand, bilateral elevation of the lower limbs and body tilting between +15° and -15° failed to cause consistent changes in sweat rate on the lifted limbs. The results imply that lifting of a relatively large part of the body affects blood return, distribution of blood, and subsequent cardiovascular responses, which may mask the local effects. Furthermore, body tilting from +90° to -6° caused a reduction in sweat rate over the upper half of the body, while tympanic and esophageal temperatures remained nearly constant. Such responses to the head-down tilt apparently involve a reflex caused by skin pressure to upper dorsal trunk and possibly also reduced metabolic rate in the supine position. It is concluded that effects of various postural changes on sweating activity involve multiple local and systemic factors, such as local blood flow, blood return, blood redistribution, cardiac output, skin pressure, and metabolic rate, but none of those appear to exert a substantial effect on whole body thermal balance.

Key words: Postural Changes, Head-down Tilt, Limb Lifting, Sweating, Skin Blood Flow, Thermoregulation, Blood Return, Skin Pressure

TELESCIENCE TESTBED FOR SPACE PHYSIOLOGICAL EXPERIMENTS
- SYSTEM OPERATION -

Masamichi YAMASHITA, Satoru WATANABE*, Niels FOLDAGER**, Takatoshi SHOJI***, Hideo SUDO*** and Flemming BONDE-PETERSEN**

Institute of Space and Astronautical Science
Yoshinodai, Sagamihara, Kanagawa, 229
* The Research Institute of Environmental Medicine, Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464
** Danish Aerospace Medical Center of Research
Rigshospitalet, FLMK 7522, Tagensvei 20, Copenhagen
*** Kawasaki Heavy Industries, LTD
Kawasaki-cho, Akashi, Hyogo, 673

Testbed experiment was conducted with several focuses on the telescience concept applied to space physiological studies. Evaluated was impacts of telescience constraints on scientific achievements. Major concerns of investigators originate in their physical isolation from experimental system. Teletools are provided for investigator to interact with his/her experiment. In general, such a situation is accompanied by a differentiation of an experimenter into two parts, i.e. investigator and implementer. Scientific requirements and engineering constraints are tossed between both side in order to plan, design and execute an experiment. Investigators loose a direct touch to their experiment once their plan is handed to engineering part. Requirements and constraints must be delivered between scientist and engineer in an appropriate manner, and interpreted properly by each side. Testbed gives an opportunity to have simulated transactions between them. As a common configuration of space physiological experiments, subjects and/or operators are necessary to be onboard. Roles of operator onboard and investigator ground should be defined with a context of "How scientist can be a scientist in his/her experiment". Typical requirements became clear for skill of operator and for training before and during missions. It is important to take advantage of having operator at close contact with subject. In order to assure investigators a full controlability on experiment, autonomous execution by operator own is requested to be harmonized with decisions expected to be made by investigator. Besides the relation between scientist and engineer, good communication between operator and investigator is a key factor to proceed experiment adequately. Human factors were one of major concerns over whole phase of testbed, from design to operation. Experimental procedure was integrated of several objectives in order to investigate physiological phenomena interact with each others. Experimental objectives, which were coordinated into single procedure, shared resources such as single human subject-operator, experiment time-line and so forth. Priority level was decided for each experimental item. Requirements of unit procedure were expressed as functional objective, FO. A method of operational management by FO style was assessed to conduct integrated space physiological missions. International fleet organized in this study gave a chance to look on cultural and sociological issues for collaborative projects.

Key words: Telescience, Testbed, Space physiology

Telescience Testbed for Physiological Experiments

Takatoshi SHOJI, Hiroyuki MATUMURA, Hideo SUDOH, Masamichi Yamashita*,

Niels FOLDAGER**, Flemming BONDE-PETERSEN**, Satoru WATANABE***

KAWASAKI HEAVY INDUSTRIES, LTD
1-1, Kawasaki-cho, Akashi-city, Hyogo Pref. 673

* INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE
Yoshinodai, Sagamihara-city, Kanagawa, 229

** DANISH AEROSPACE MEDICAL CENTRE OF RESEARCH
Rigshospitalet, FLMK 7522 Tagensvei 20 Dk-2200 Copenhargen

*** THE RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE, NAGOYA UNIV.
Furo-cho, Chikusa-ku, Nagoya, 464

In general, space experiments would be executed by crews in-orbit with the help of automonous equipment in behalf of principal investigators (PI) on-earth. In this case, flexible research is used to be restricted for the simplification and fixation of test sequences.

Telescience is such a concept that PI is able to perform the realtime teleoperation and to lead his/her own experiments. This report deals with the results of telescience testbed in space physiology using water immersion facility at the Research Institute of Environmental Medicine, Nagoya University, and descrives about system operation and simulating hardware.

The features of this testbed are as follows;

(1) Experimental operations are done by operator
PI (Principal Investigator) is physically separated from experiment.
PI communicates with operator/experiment by teletools.
The operator is not trained in some of the applied procedures.

(2) Experiment is conducted by engineers
Scientific requirements are intepreted by engineers.

(3) Several scientific experiments are integrated into one experiment procedure
Timeline is a resorce shered by PI's.
Constituent experiments are prioritized.

(4) Data/Command communication capasity/type is limited

Some of constraints were overemphasized in this testbed in order to measure impacts of telescience configuration on quality of science.

TELESCIENCE TESTBED FOR PHYSIOLOGICAL EXPERIMENTS.
- APPLICATION FOR WATER IMMERSION EXPERIMENT-

Masafumi TANAKA, Hisao SEO, Satoshi IWASE, Sayumi KANEKO, Tadaaki MANO, Satoru WATANABE, Nobuo MATSUI, Niels FOLDAGER* and Flemming BONDE-PETERSEN*

Research Institute of Environmental Medicine, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-01 Japan
*Aerospace Medical Clinic, University Hospital, Rigshospitalet 7522, Tagensvej 20, DK-2200 Copenhagen, Denmark

In order to clear up the causes of various physiological changes in space, water immersion experiment is usually adopted in terrestrial simulation studies, even though there are some noticeable discrepancies between the data obtained in space or in simulated situation. We, however, dared to choose the head-out water immersion experiment regarded as weightless situation, and further, the experiment was conducted through telescience-testbed method (see definition in the previous two papers).

The following physiological data were collected : 1. ECG, 2. blood analysis, 3. peripheral blood pressure, 4. peripheral blood flow, and 5. echocardiographic analysis. The data obtained through the restricted conditions of telescience-testbed method showed no difference those from conventional method. Thus, the method adopted here emphasizes that the telescience-testbed method is quite usable for the experiments controlling from topographically separated points.

Keywords: Telescience-Testbed, Water Immersion Experiment

Spinoffs of Space Development Technology for Medicine and Space Medicine

Kazuyoshi Yajima
Nihon University School of Medicine

Japanese space policy has been changed recently, and manned space activity has first been recognized in the new policy. There have been many spinoffs derived from space development technology for medicine, as well as for space medicine. Nasa has published the spinoffs twice, the first in 1976 and the second in 1986. Comparison the former with the latter is very interesting, because they are clearly indicating the different situations of NASA at those times when they needed to advertize the space utility in 1976, and when they had confidence for their productivity from space in 1986.

It should be noted that the more important spinoffs of medicine has come from general, non-medical technology of space. Medical applications would be actually a lot concerning from almost all new technology, material, and method. Some new acknowledge in space medicine will give a benefit to on the ground medicine, and vice versa. It is also no doubt that the final purpose of space medicine is to make a mechanism of human body clear, even if man is in space, or on the ground.

Key words: Technology transfer, Space medicine, Spinoff for medicine,

ON ANTARCTIC SPACE RELATED HUMAN FACTORS RESEARCH

Taketoshi MORIMOTO
Kyoto Prefectural University of Medicine
Kamigyoku, Kyoto 602

Antarctica has long been acknowledged as an analogue for space in the sense that scientists in both Antarctic and space station are involved in isolated and confined environments. In order to facilitate all the disparate work being performed by both space and Antarctic agencies, an ad hoc Group on Antarctic Space-related Human Factors Research was established at the Twentieth Scientific Committee on Antarctic Research (SCAR) Meeting in 1988, and the first meeting of the group was held in Aberdeen in June 1989. At the meeting, mutual problems faced both in polar regions and space environments were discussed, which include research areas of behavioral, physiological, immunological, sociological, psychological, environmental engineering and medical sciences. Out of these areas, psychological and immunological areas were chosen as the field to start with to enhance the performance, health and safety of people in both settings. The importance of international co-operation and co-ordination was stressed to increase the quality and quantity of research, and also to make cross-cultural studies which will be required for future co-operation at space stations.

Key words: Antarctic Space-related studies, Psychology, Immunology

ORBITING ATMOSPHERIC RADAR

Toru Sato[1], Nobuyuki Kaya[2], Iwane Kimura[1] and Hiroshi Matsumoto[3]

1) Dept. of Electrical Engineering II, Kyoto University, Kyoto 606, Japan
2) Dept. of Instrumentation, Kobe University, Nada, Kobe 657, Japan
3) Radio Atmospheric Science Center, Kyoto University, Uji, Kyoto 611, Japan

Importance of measuring the earth's upper atmosphere has widely been understood in relation to the advances of studies on environmental pollution. Among various techniques for remote sensing the atmosphere, satellites and MST radars have played complementary roles.

It is thereby natural to consider the possibility of installing such radars on a satellite. A similar project of Tropical Rainfall Measuring Mission, which includes installation of a dual-frequency rain radar as one of most important instruments, is in progress. However, the radar uses 10–30GHz band which is sensitive only to precipitation, and also no Doppler capability will be introduced.

Here we examine the feasibility of installing a UHF-band large Doppler radar on board a space station. A radar with 100kW peak output power and with an array antenna of 100m diameter on a circular orbit of 500km height is examined as an example. It is shown that the radar is capable of observing two separate height regions of 0-15km and 100-500km with a vertical and horizontal resolution of a few to several kilometers.

Its capability is comparable to existing ST (Stratosphere-Troposphere) radars in the troposphere and lower stratosphere, and to medium-size IS (Incoherent Scatter) radars in the ionosphere. A smaller sized radar will also be practical, but with a poorer resolutions.

Key words: Orbiting radar, Remote sensing, Space Station

Study of Spacecraft Environment Related to Space Plasma Physics

Susumu SASAKI, Yuzo WATANABE, Koichiro OYAMA, Nobuki KAWASHIMA, Nobuyuki KAYA(1), Tousei SAI(1)
Toshiaki YOKOTA(2), Sadao MIYATAKE(3), Eiichi SAGAWA(4), Masahiro ONTA(5) and Fumio TOHYAMA(6)

Institute of Space and Astronautical Science, Yoshinodai, Sagamihara, Kanagawa 229
1 Kobe University, Nada, Kobe 657
2 Ehime University, Bunkyo-cho, Matsuyama 790
3 University of Electro-Communications, Chofu, Tokyo 182
4 Communications Research Laboratory, Kitamachi, Nukui, Koganei 184
5 Tokyo Metropolitan University, Fukazawa, Setagaya 158
6 Tokai University, Kitakaname, Hiratsuka 259-12

Utilization of space in space station era requires a well-organized diagnostic system for spacecraft environments. Such an advanced diagnostic system enables us to make a new field research in space science. A spacecraft moving in the ionosphere generates a plasma wake, collisionless shock structure, plasma turbulence and surface interaction. These spacecraft-generated effects are similar to the phenomena surrounding the space bodies such as planets and comets in the solar wind and satellites moving in the planet magnetosphere. From a standpoint of space science, a spacecraft is regarded as an experimental apparatus to study the interaction of space medium and a solid body. The onboard diagnostic system is regarded as an instrumentation to study the interaction. This paper describes the subjects to be studied and future plans in this research field.

Key words: Spacecraft Environment, Body-Space Medium Interaction

STUDY ON THE DETERIORATION OF MATERIALS USED IN SPACE BY THE OXYGEN ATOMS - TRIAL PRODUCTION OF ATOMIC OXYGEN GENERATOR -

Chobei YAMABE, Satoru TAKASE, and Kenji HORII

Nagoya University, Faculty of Engineering, Department of Electrical Engineering
Furo-cho, Chikusa-ku, Nagoya 464-01

It is very important for the design of space flyers that the deterioration phenomena and it's mechanism of the materials used in space by the oxygen atoms and the ozone molecules are studied. A coaxial cylindrical double discharge type generators for the oxygen atoms and ozone molecules are tried to produce them.

A pre-discharge prior the main-discharge is used to obtain the stable diffuse glow discharge and to get the atomic oxygens and ozone molecules effectively in oxygen mixtures at atmospheric pressure.

The experiments reported here have been put stress on getting the fundamental characteristics of the generators with double discharge. It has been confirmed that this type of generator is effective on the ozone generation, so on the oxygen atoms, too.

Key words: Deterioration of Material, Space, Oxygen Atom, Ozone, Double Discharge

UTILIZATION OF MICROWAVE ENERGY TRANSMISSION TECHNOLOGY IN SPACE

Hiroshi MATSUMOTO[1] and Nobuyuki KAYA[2]

1 Radio Atmospheric Science Center, Kyoto University, Uji, Kyoto 611
2 Dept. of Instrumentation, Kobe University, Rokkodai, Nada, Kobe 657

Microwave energy transmission technology is indispensable not only for the Solar Power Satellite (SPS) in the distant future, but also for many other practical applications in the near future both in space and on the ground. The latter includes space-to-space power supply from a small-sized SPS to the Space Station and wireless energy supply to a stratospheric aircraft. We propose an METS (Microwave Energy Transmission in Space) experiment using the Space Flyer Unit (SFU) to develop these basic technologies. Two fundamental problems will be studied by the METS experiment; One is a development of a control system of the microwave energy beam which enables us to achieve an accurate pointing to the energy receiver. The other is the study of nonlinear propagation characteristics of the microwave energy beam through space plasmas and the counter effects of the microwave beam on the plasma environment.

Our three-year development program for the METS experiment is actively in progress. The goal of the program is to accomplish a microwave transmission system installed onboard the SFU. We challenge five development items as follows; (1) Retrodirective antenna having wide coverage of the tracking angle with pilot signals of two frequencies. (2) Microwave beam control system by computers (Neural computation). (3) Microwave high power FET amplifiers. (4) Design of the transmitting antenna. (5) Digital phase shifters driven by a simple command system with a high speed. Also, we have a plan to carry out a rocket experiment (MINIX-II) for tests of the newly developed microwave beam control system and for examinations of microwave plasma interactions observed by the first MINIX rocket experiment.

Key word: Solar Power Satellite, Microwave Energy Transmission, METS Experiment, SFU

CONTROL OF MICROWAVE BEAM POINTING WITH NEURAL COMPUTATION

Nobuyuki Kaya[1], Hiroshi Matsumoto[2] and Makoto Nagatomo[3]

1 Dept. of Instrumentation, Kobe University, Nada, Kobe 657
2 Radio Atmospheric Science Center, Kyoto University, Uji, Kyoto 611
3 Institute of Space and Astronautical Science, Sagamihara, Kanagawa 229

The microwave energy transmission needs a very high accuracy in the control of the microwave energy beam pointing. Therefore, the development of the microwave beam control technique is very important for the wireless energy transmission. Two systems are proposed for the microwave beam control. One is a retrodirective antenna, and the other a computer control system. While the retrodirective antenna needs complicated phase conjugate circuits (PCC), the computer control system does only computers with digital phase shifters. Then, it is likely that the computer system is simpler and more flexible.

Neural computation is an useful algorism for the microwave beam control because of its parallel processing. At first we examine an application of "Back propagation algorism" to the microwave beam control. The back propagation is a learning algorism of the neural network, and very useful for pattern recognition. Receiving levels by a rectenna are used by the computer for control of the phase shifters of the transmitting antenna. We can obtain good results in the energy transmission even though the transmitting antenna is distorted.

Key word: Microwave energy transmission, Retrodirective antenna,
Computer control, Neural computation.

DEVELOPMENT OF COMPLETE RETRODIRECTIVE SYSTEM

'H.MATSUMOTO,''N.KAYA ,''' N.NAGATOMO
'''' Y.FUJITA, K.NAKATSUKASA, K.IZICHI, K.EISIMA, Y.YAMAGUTI AND T.HASHIZUME

The purpose of this study is to develope complete Retrodirective system for microwave transmission. The previous Retrodirective system can not be adapted to Energy transmission, especially for long distance, because of its pointing error and phase ambiguity. In the present study systematical analysis of Retrodirective system is conducted to design the optimized Retrodirective system and proves that ansymmetrically two tone pilot signal system ,which is originally designed in this study, is the most reasonable one. To compare the present system with previous one tone pilot signal system experimental study is achieved by using BEM(7 units).As the result the present Retrodirective system shows complete phase conversion required for exact beam pointing of Retrodirective system . .

Key words; ,PHASED ARRAYS, ADAPTIVE CONTROL, ENERGY TRANSFER,

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'Kyoto Univ. ''kobe Univ., ''' ISAS, '''' Mitsubishi Electric Corp.

EXPERIMENTAL VERIFICATION OF DEPLOYABLE ANTENNA BY ROCKET

Koryo MIURA, Tadasi TAKANO and Junichiro KAWAGUCHI

Institute of Space and Astronautical Science
Yoshinodai, Sagamihara, Kanagawa 229

The purpose of the present paper is to report a preliminary study on the zero gravity experiment of a large deployable antenna reflector on-board a S-520 rocket. The objective antenna is a tension truss antenna which will be used as the 10 m reflector of MUSES-B satellite for VLBI observation in space. Since kinematics of deployment of such a large reflector having both complex and delicate structure is difficult to estimate, and the simulation of it on the ground is almost prohibitive, the experiment using a sounding rocket has been planned. Environmental conditions of S-520 rocket, experimental instrumentation, data acquisition, and experimental sequence are discussed.

Key words: Deployable Antenna, 0-g Experiment

MASS TRANSFER CHACTERISTICS OF OXYGEN AND CARBON DIOXIDE IN AN ARTIFICIAL GILL

Hiroya Matsumoto, Akira Kakimoto, Shuichi Sato

Mitsubishi Heavy Industries, Ltd.

A study was made on the mass transfer rate of O_2 and CO_2 gas in an artificial gills (a gas exchange module in a liquid - liquid system employing a hydrophobic microporous membrane). It is necessary for artificial gulls to incorporate two functions: (a) a function to prevent the movement of water and salt between liquid phase I and liquid phase II, and (b) a function to mutually exchange dissolved O_2 and CO_2 through a membrane. A hydrophobic microporous membrane imbued with these functions was selected and, from the study of mass transfer mechanisms, the following results were obtained:

(1) With the artificial gill make of a hydrophobic microporous membrane, it was possible to conduct the exchange of O_2 and CO_2 gas dissolved in water in a similar manner as a fish in the ocean exchanges O_2 and CO_2 through its gills.

(2) Based on the film theory, the mass transfer resistance in an artificial gill can be expressed by the following formula:

$$1/K = 1/ko + 1/P + 1/ki$$

Where ko is the mass transfer coefficient through a liquid film outside the hollow fiber, P is the permeability coefficient of the membrane, and ki is the mass transfer coefficient through a liquid film inside the hollow fiber.

1 The principal resistance to gas transfer in an artificial gill is found in the liquid film on both sides of the membrane (1/one ki + 1/ko). The resistance of the membrane (1/P) is negligible compared with that of the liquid film.

2 ki corresponds closely to the theoretical solution of Schenk and Dumore derived from the heat and mass transfer analogy.

3 The following empirical formula expresses the relationship between ko $(m^3(STP)/m^2 \cdot Pa \cdot S)$ and the liquid flow velocity outside the hollow fiber uo (m/s):

$$ko\ (O_2) = 5.52 \times 10^{-11}\ uo^{0.794}$$

$$ko\ (CO_2) = 8.11 \times 10^{-10}\ uo^{0.492}$$

(4) From these results we designed the artificial gill type small closed enviroment life support system.

Key words: CELSS, Artificial Gill

FUNDAMENTAL STUDY ON EXPERIMENTAL WASTE WATER TREATMENT MEMBRAME DISTILLATION

Hiroya Matsumoto, Akira Kakimoto, Shuichi Sato and Hiroaki Matsumoto

Mitsubishi Heavy Industries, Ltd.

The water recycle utilization technology in a space station is essential to experiments of various animals and plants including human habitation. A treatment process combined with a membrane separation technology such as microfiltration, ultrafiltration, reverse osmosis and membrane distillation, is now under consideration, among which the membrane distillation method is attracting attention as a main process. With respect to the recycle system of water discharged at life science experiments of a space station, fundamental tests of the membrane distillation method and pre-study of the system have been conducted with the following confirmed.

(1) In comparison with conventional membrane separation methods (such as ultrafiltration, reverse osmosis), the membrane distillation method has a good separability of organic matter such as urea, uric acid, creatinine and also has more than 99.9% separability of ammonia if the pH is maintained below 4, thus presenting superb performance as a main process of a water recycle system.

(2) A system combined with the prefilter, the membrane distillation, the ion exchanger, the ultra violet sterilization, is excellent in equipment volume, weight, power consumption, water recovery rate and applicability under the μG.

Key words: Space Station, Membrane Distillation, Waste Water Treatment, Membrane Separation

Evaluation of Swirl Flow Cold Plate under μ-g Environment

Hiroyuki Yamada, Tatusaburo Nakamura
Technical Institute, Kawasaki Heavy Industries, LTD.,
Akashi, Hyogo 673

Tomonao Hayashi, Akira Ohnishi
Institute of Space and Astronautical Science,
Yoshinodai, Kanagawa 229

The researches of a two-phase thermal control system of spacecraft are now underway at various organizations in the world. Swirl Flow Cold Plate (SFCP) utilizing the latent heat of coolant is one of the devices that absorb the heat from equipments in spacecraft. This device is considered as proper evaporative cold plate since the vapor-liquid phase separation incidentally occurs in spiral tube. However, its superiority and differences from other evaporative devices are not evidently verified in our experiments so far because of 1-g environment.

In order to evaluate the feasibility and the performance of SFCP, the concepts of the experiments under reduced gravity environment are expanded in this report ; the experiment of visualizing vapor-liquid behavior and ensuring the improvement of the thermal performance because of the secondary flow/centrifugal force effect in spiral tube. These experiments will be conducted by drop tower, parabolic flights of aircraft and sounding rocket.

Key words : Swirl Flow Cold Plate, Thermal Control System,
μ-g Environment

LATENT THERMAL ENERGY STORAGE UNDER MICROGRAVITY

Kotaro TANAKA, Yoshiyuki ABE, Katsuhiko KANARI, Osami NOMURA,
Yoshio TAKAHASHI, and Masayuki KAMIMOTO

Electrotechnical Laboratory,
1-1-4 Umezono, Tsukuba, Ibaraki 305

Thermal Energy Storage (TES) using Phase Change Materials (PCM) under microgravity condition, provides a number of desirable applications. TES system can be used to provide or reject thermal energy for experiments and/or material processing at constant temperature levels. Further, TES system incorporated with the solar receiver is to be used for Solar Dynamic Power System (SDPS) and also to be effective to reduce the area and mass of the heat rejection radiator system.

Fluoride salts, such as lithium fluoride, calcium fluoride, magnesium fluoride, and their eutectic mixtures, are candidate TES materials in the temperature range from 900 K to 1300 K. These salts have high latent heat on fusion, but they have large volumetric change upon melting (10-30 %).

One of the serious problems encountered when PCM is encapsulated in a canister is the generation of voids and stress concentration associated with volumetric change on fusion of PCM. Typical examples of phase change behavior within the canister both under one-gravity and micro-gravity condition are discussed. The present paper proposes a new concept which can reduce the mechanical stress of the containment wall structure. The concept is the addition of fins which are not wetted by PCM. The expansion of liquid phase can be directly absorbed into the volumetric reduction of fin material and liquid phase also can be transferred to the center of the canister through the path of the gap created between solid phase PCM and the fin surface. Therefore, the transferability of liquid phase not only relaxes the mechanical stress but also enhances the heat transfer rate.

In order to obtain the experimental information on phase change behavior inside the canister, we have conducted the in situ visualization experiment using the X-ray Computerized Tomography (CT). The X-ray CT is effective for continuous observation of the meniscus inside the metallic canister. The high temperature visualization results on solidification process (calcium fluoride 19.5 mol%-lithium fluoride 80.5 mol% within a carbon canister) are presented. The formation and the distribution of voids are discussed in detail.

Further, the authors have developed the numerical computer program which simulates the moving boundary problems on phase change including the effect of the formation of voids and free liquid surface. Calculated results of the solidification process inside the cylindrical canister are given. A detailed theoretical analysis on mechanical and thermal stress is in progress. A typical result of the stress distribution and the deformation of the canister caused by melting process is also shown in this paper.

Key words: Latent Thermal Energy Storage, Phase Change Material,
Heat Transfer

DEVELOPMENT OF MECHANICAL COOLER FOR SPACE OBSEVATIONS

H. Okuda, N. Tanatsugu,[1] T. Matsumoto,[2] Y. Matsubara,[3]
H. Nagano,[4] T. Hashimoto,[5] M. Murakami,[6] J. Inatani,[7]

1. Institute of Space and Astronautical Science
2. Nagoya University
3. Nihon University
4. Toyama Universtiy
5. Tokyo Insitute of Technology
6. Tsukuba University
7. Nobeyama Radio Observatory

Cryogenical cooling has become a cruicial technique for modern astronomical observations in space. In particular, it is inevitable in infrared observations because ,otherwise, the observations are fatally disturbed by extremely strong thermal radiation predominantly emitted in infrared region peaking near 10 microns.

In the past and presently planning missions, cryogen coolant has been used for the cooling of the instruments, where quite a large amount of coolant is necessary to warrant a certain life time of the mission. For keeping away the environmental heat from the coolant, a bulky and heavy vacuum cryostat should be prepared.

Here, we propose development of mechanical coolers to replace the cryogen cryostats. Success of the development will lead to substantial reduction of scale and weight of the istruments; we no more need a bulky and heavy vacuum chamber for the cryostat and hence a larger telescope would be easier to be built within the severe limitation in size and weight,which is always requested in space experiments. The development will be undertaken in the collaboration of scientists and experts in relevant engineering.

COSMIC RESOURCE MATERIALS AND THEIR IMPACT PROCESSES

Yasunori MIURA

Faculty of Science, Yamaguchi University
Yoshida, Yamaguchi, Yamaguchi 753

Various cosmic materials hit by impact process to the Space Station are classified to discuss the possibility of resource materials, establishment of prior sensing devices, impact avoidance, and development of resisting-pressure materials on the bases of planetary earth sciences, material sciences and security problem of the Space Station.

Cosmic solid materials of meteorites and cosmic dusts show relatively short-time destruction within the limited areas and re-distribution process of the lithophile and siderophile elements in the cosmic space, which should be detected in advance to avoid the destruction of all the Space Station. Cosmic particles of the galactic cosmic ray, the solar flares and the solar wind show relatively the long-term destruction throughout the wide area and supply of Hydrogen and Helium-3 for the 21st-century nuclear fusion energy, which could not be free from the collision and should be used the resisting-pressure materials by periodic changing within the life time. The cosmic-originated fragments are more serious impact materials than the orbital fragments from the terrestrial origin which can be used as ready-made resource materials in the space.

Cosmic resource materials of Helium-3 are considered to be found in the lunar regolith and soil and younger igneous rocks of the planetary body and fragments without atmosphere, which can be collected from older fine and powdered cosmic materials even in the Space Station. The Helium-bearing materials should be detected by using the in-situ compact SIMS (-laser) apparatus on the cosmic-dust collector in the Space Station.

Key words: Cosmic resource materials, Impact process, Helium-3, Cosmic-duct collector, Prior sensing devices, Impact avoidance, Resisting-pressure materials, Meteorites, Hydrogen, Life time of the Space Station, Orbital fragments.

SOME PROBLEMS OF SAFETY REQUIREMENT ON SPACE MATERIAL PROCESSING EXPERIMENTS

Akira B. SAWAOKA
Center for Ceramics Research, Tokyo Institute of Technology
Midori, Yokohama 227

We met some difficult problems in the preparation process of the space experiments, especially space shuttle/spacelab utilization. Safety requiement of space shuttle utilization for payload is really severe for material invesigator. Sometimes, essential physical meaning of the experiments has been spoiled for satisification of the safety requirement. We have to look for a new pavement for harmonic approach in the early planning stage of space experiment in the space station. As an example, a difficulty of silicon crystal growth experiment using a gradient heating facility is demonstrated on the point of safety requirement.

Keywords: Safety Reqirement, Material Processing, Space Shuttle/Spacelab

FUNDAMENTAL EXPERIMENTS OF SMALL GRAVITY BY 50-CLASS DROP TOWER (1ST REPORT -DEVELOPMENT OF DROP TOWER-)

Kazuo MAENO,* Yutaka HANAOKA,* Toshiki KABUTOMORI,**
Toshimitsu GOTO,** Yuichi WAKISAKA,** and Keizo OHNISHI**

* Muroran Institute of Technology
Mizumoto, Muroran, Hokkaido 050
** Japan Steel Works, Muroran Research Institute
Chatsu, Muroran, Hokkaido 050

In order to progress the ground level research activities on microgravity, 50m-class drop tower was developed in atmospheric surroundings. Taking into account the aerodynamic drag that was empirically obtained for 2/5 scale model, onedimensional analysis on low gravity environment was performed, from which drag-shield type capsule has been designed. The operation of 50m-class drop tower was investigated to have satisfactory performance, and the upper low gravity level was limited within 4 ngrv. Several fundamental experiments were discussed on fluid dynamics including the mercury drop formation, which were conducted by our drop tower.

Key words: Drop Tower, Microgravity, Fluid Dynamics, Liquid Metal

IMPROVEMENT IN REDUCED GRAVITY ENVIRONMENT ON A PARABOLIC FLIGHT AIRCRAFT

Fumio TAKEI, Shozo FUJITA, and Kasumi IKEGAMI
FUJITSU LABORATORIES LTD.
10-1, Aorinosato-Wakamiya, Atsugi-shi, Kanagawa, 243-01

Tsuyoshi KOTANI
FUJITSU LIMITED
1015, Kamikodanaka, Nakahara-ku, Kawasaki-shi, Kanagawa, 211

Reduced gravity experiments aboard a parabolic flight aircraft like NASA's KC-135 is extremely useful for testing equipments which are designed to space experiments. Although parabolic flight is applicable to several fields of investigation, the residual gravity of some 10mG will affect on the behaviour of liquid or surface dynamics. It is possible to decrease the residual gravity by free-floating an experiment module. But, handling the module under reduced gravity was so difficult that floating time of the experiment module is only 2 or 3 seconds in average so far.

We developed an apparatus which makes the experiment module free-float mechanically with repellent of spring. Using this apparatus in the KC-135 parabolic flight aircraft, it becomes easy to free-float an experiment module, and floating time was extended to more than 6 seconds in average.

Even under the free-floating state, the experiment module is affected by the resisting force from air. Lower limit in reduced gravity environment during free-float was estimated to be about 100 μG.

Key Words : reduced gravity, parabolic flight, KC-135, free-floating

Development of the electrostatic positioning instrument using alternative electric field

Masaaki OGIHARA, Yuji IKEGAMI, Tsumoru FUJII
Munetaka KURIBAYASHI* and Michio AOYAMA**

* Ishikawajima-Harima Heavy Industries Co.,Ltd.
3-1-15 Toyosu,Koutou-ku,Tokyo 135
** Nishinippon Institute of Technology
Kanda-cho, Miyako-gun, Fukuoka 800-03

This paper describes an electrostatic levitation instrument which was developed at Nishinippon Institute of Technology and IHI Co.,Ltd.to enable experiments to conduct containerless material processing tests in space.

The apparatus is consisted of two dimensional quadrupole electrode and a couple of sphere electrode.
The alternating current voltage is applied to the former electrode and the direct current voltage is applied to the latter one.
The electric field produced by these voltages gives the centering and the levitation force to the charged object.

This instrument was able to give the stable levitation to the charged particle with 4mm in diameter ,1.5mg in mass and 6E-10(C) in charge under the terrestrial condition.

We have concluded that this type of electrode system is promising as the instrument giving the containless processing in space.

key words:Electrostatics, Levitation, Positioning, Quadrupole

Gas Evaporation in Low Gravity with Drop Tower

Minoru DOHI, Shinya SAWAI, Toshiaki GOTO, Toshikazu SATO
Manabu KATO, Nobuhiko WADA

Department of Physics, Nagoya University
Furo-cho, Chikusa, Nagoya 464-01

In this report we describe the gas evaporation in the condition of suppressing gravitational convection. Following two experiments were performed.

(1) The experiment of the gas evaporation in the low gravity using a drop tower with 14m height was carried out. Smoke ball of fine particles were observed in the environment. We set a sample collecting rod in a evaporation bulb to investigate particles at various position in a smoke ball, and studied them by microscopy.

(2) By using the evaporation device with the top heating vertical furnace, we can observe various forms of zinc fine particles produced at various temperature and pressure of gas environment. A number of zinc particles having clear habits were obtained. Dodecagonal thin plates which have never reported at normal gas evaporation were found in the condition of He 100Torr gas environment.

Key Words : Gas Evaporation, Convection, Fine Particles
Low Gravity, Drop Tower, Smoke Ball
Top Heating Vertical Furnace, Crystal Growth

PLASMA CVD IN LOW GRAVITY WITH A DROP CAPSULE

Nobuhiko WADA, Masaaki TANI, Toshiaki GOTO,
Toshikazu SATO, and Manabu KATO

School of Science, Nagoya University
Nagoya 464-01, Japan

The influence of gravitational convection to the plasma was shown by the arching of electric discharge. In the low gravity of 1.4 sec. by a drop capsule, RF discharge of Ar gas without arching between electrodes was observed. In the mixed gas of C_2H_5OH, H_2, and/or Ar, the same experiment carried out, and found the depositions of organic materials on the tip top of the electrodes. By the SEM and the TEM observation, dendrite of graphite, organic films with ripples of interesting shapes were often observed in the low gravity experiment. Diamond was detected by electron diffraction analysis together with the graphite and organic films.

A single type of drop capsule without drag-shield was developed for this experiment. The capsule was designed so slim that the drag-force of air was to be minimized. Low gravity of less than $4 \cdot 10^{-3}$ G maximum at the bottom of drop tower of 14 m was obtained for 40 kg of weight.

This short time experiment with plasma in low gravity was suggesting the many interesting behaviors of plasma in space experiment in future.

Key words: Plasma CVD, Low Gravity, Drop Capsule,
Dendrite of Graphite, Ripple of Organic Film,
Diamond, Drag-shield, Drag-force, Drop Tower,
Space Experiment

Solar Cell Production in Space by Molecular Beam Graphoepitaxy

Y. Hamakawa, H. Takakura and T. Kanata
Faculty of Engineering Science, Osaka University
Toyonaka, Osaka 560, Japan.
T. Kariya
Faculty of Science, Kochi University
Akebonocho, Kochi, Kochi 780, Japan

A systematic investigation of a molecular-beam-deposition-based graphoepitaxial growth of germanium have been performed in order to establish technologies to produce high-efficiency light-weight GaAs/AlGaAs solar cells in space for space utilization. Benefits of the space environment such as the zero-gravity and the high-vacuum with an abundance of solar energy can be fully utilized in solar cell production. Substrate employed in this experiment is fabricated by Ni plating as the replica of the relief of texture-etched Si(100) wafer. In order to enhance the graphoepitaxy effect, we employed the Ge-Au or Ge-Al eutectic alloy and recrystallization by Ar laser scanning, which realizes a kind of liquid phase crystal growth and can be expected to grow larger grain size.

As a result, we can obtained a orientation-controlled polycrystalline film with the grain size of around 10 μm in 4 μm-thick-Ge film. However, the graphoepitaxy occurs only a part on the substrate. This indicates that the uniformity of the substrate temperature and the reproducibility of laser scanning conditin are very critical. The optimization of these conditions is the earliest task in this project.

key words: Solar cell, SPS, Graphoepitaxy, zero gravity, high vacuum

ADHESION PHENOMENA BETWEEN DISSIMILAR MATERIALS IN SPACE ENVIRONMENT AND DEVELOPMENT OF JOINING METHOD AT ROOM TEMPERATURE UTILIZING THE ADHESION PHENOMENA

Tadatomo SUGA

University of Tokyo, Faculty of Engineering,
Dept. Precision Engineering, Hongo, Tokyo 113

In the present paper we report on the development of a new method for joining of different materials at room temperature in space environment. The method is based on the utilization of the adhesion phenomena between two clean materials surfaces which can be observed often with mechanical components in an ultrahigh vacuum chamber. Clean and activated surfaces are indispensable for achieving a good bonding. Three methods to get such clean surface were examined: 1) frictional motion, 2) ultrasonic vibration, and 3) ion bombardment. The first method requires no large power supply, whereas the last is more suitable for joining small devices which should be kept away from any surface damage. The result of the preliminary experiments shows that the joining process requires no ultrahigh vacuum but only high vacuum which can be easily realized on the space station.

Key words: Adhesion, Joining, Room Temperature Joining,
Frictional Welding, Ultrasonic Joining,
Ion Bombardment

REDUCED GRAVITY EXPERIMENT ON AIRPLANE

Akira IWASAKI, Shunsuke HOSOKAWA
Mitsumori TANIMOTO, and Isao KUDO
Electrotechnical Laboratory
1-1-4, Umezono, Tsukuba-shi, Ibaraki 305 Japan

Shozo FUJITA and Fumio TAKEI
Fujitsu Laboratories Ltd. Atsugi
10-1, Morinosato-Wakamiya, Atsugi-shi, Kanagawa 243-01 Japan

The experimental set-up to visualize the liquid behavior under a reduced gravity condition was developed and boarded on NASA's KC-135 airplane in November 1988. During the parabolic flight, Freon-11 was heated from the bottom copper plate and interference fringes to represent temperature gradient in the liquid were obtained with a Jamin interferometer.

On the ground the natural convection took place in a form of a periodic flow and the heat removal rate from the bottom was enhanced. On the contrary, the stratified layer was formed in the entire period of the paraboric flight. The reason was supposed that the buoyancy force induced the convection but was not strong enough to break this layer only in the reduced gravity condition. Therefore, heat transportation was restricted and a bubble appeared due to the heat accumulation.

As residual gravity during parabolic flight was not negligible, it affected on the liquid behavior. To quantify this effect, the interference fringes and the gravity data were investigated together.

Key Words: parabolic flight, reduced gravity, Freon-11, convection

ANALYSIS OF MARANGONI CONVECTION UNDER CHANGING GRAVITY FIELD

Yasunori NIIYATA, Toshinori TERAKADO, Hiroshi SAKUTA and Toshio SUZUKI

Nagaoka University of Technology
the University of Tokyo

Effects of changing gravity field to the Marangoni convection, which is [illegible] under microgravity, are estimated by both of numerical analysis and a flow visualization experiment.

Free fall experiments are assumed for changing gravity field, where gravity acceleration becomes 0.01G from 1G. the flow visualization experiment is implemented by He-Ne laser and a video camra.

As a result, it is found by the comparison with flow visualization that the numerical analysis is valid and a proper condition for free fall the experiment can be proposed.

Key words: Marangoni convection, flow visualization, Numerical analysus
Microgravity, changing gravity field

Fundamental Studies on Marangoni Convection and Natural Convection in Melt

Akira HIRATA[1], Masato TACHIBANA[1], Shin-ichi NISHIZAWA[1]
Yasunori OKANO[2], Tsuguo FUKUDA[2]

1)Department of Chemical Engineering, Waseda University
3-4-1, Ohkubo, Shinjuku-ku, Tokyo 169 JAPAN
2)Institue for Materials Research, Tohoku University
2-1-1, Katahira, Aoba-ku, Sendai 980 JAPAN

During growth of bulk single crystals under microgravity at Space Station, Marangoni convection in the melt affects quality of single crystals significantly. Therefore, it is necessary to clarify Marangoni convection phenomena and to develop control method of Marangoni convection.

The Marangoni and natural convections formed spontaneously in the melt inside a two-dimentional rectangular open boat were investigated by means of an order-of-magnitude evaluation and a numerical analysis according to the finite diference method. A quantitative evaluation was made of the Marangoni number, Grashof number, gravity level, Prandtl number, melt depth and interfacial contamination phenomena, all of which affect the interfacial velocity and the velocity distribution of the melt convection. It was concluded that Marangoni convection as well as natural convection is important when the melt is shallow.

Interfacial flows of molten $LiNbO_3$, $LiTaO_3$ and TiO_2 were observed. Temperature distributions on the interface of molten $LiNbO_3$ and $LiTaO_3$ were stable, and fluctuations of flow patterns almost did not affect the temperature distributions. On the other hand, which of molten TiO_2 depended on the interfacial flows. This suggests that the Prandtl number of molten TiO_2 is higher than that of molten $LiNbO_3$ and $LiTaO_3$. In order to understand the relation between the interfacial flow and bulk flow, fluid flows in silicone oils with various viscosities were visualized. The fluid flows were observed under (1) a side heating and botton insulating condition, (2) a botton heating condition and (3) a side and bottom heating condition. Steady and stable spoke patterns were observed under the side heating and botton insulating condition. The spoke patterns were broken when the temperature difference between the botton and center of the interface was large. A stability diagram for flow in a vessel with a free interface are presented.

Key words: Marangoni convection, Natural convection, Microgravity, Numerical analysis
Molten oxide, Single crystal, Crystal growth, Interfacial Phenomena
Fluid mechanics

Simulation Experiment of Convection Flow in Si Liquid under Microgravity

Kouji Mitachi Osami Saito
Toyohashi University of Technology

Tatau Nishinaga
Tokyo University

The experiment of the Si crystal growth in space under microgravity is planning to research the mechanism of crystal growth, impurity striation and surface oxidization.

To perform the experiments in space successfully with a few attempt, the examination with computer simulation is very important. Till last year, simulation of crystal growth in space have been developed. In the works, the convection flow has been ignored. However, current research point out that the convection flow driven by microgravity and surface tension, i.e. natural and Marangoni in liquid, could not been ignored.

Then this work deal with the computer simulation of convection flow in Si liquid to analyze the effect of convection to crystal growth in space. Simultaneous simulation of crystal growth and convection is very complex. So here, the only partial differential equations for temperature and solute are numerically solved for examination of natural and Marangoni convection flow.

The simulation results are obtained as follows.

(1) Marangoni flow is dominant in space, and growing as Marangoni number becomes larger. Consequently Nusselt number in the solid/liquid interface near free surface becomes lager. From this result solid Si near the free surface is consider to be melt more than that of another place.

(2) The effect of gravity to convection flow is depend on its direction. Then the posture of instrumentation in space must be considered.

(3) The shape of flow is effected by the shape of Si liquid.

(4) However in the case of small Marangoni number and Raylei number, both convection flows are weak. In our experiment, both numbers are relatively small. Then the convection flow is considered to be not effective.

NUMERICAL SIMULATION OF SOLIDIFICATION UNDER MICROGRAVITY

Koji YANAGAWA and Naomichi TAKEDA

National Development Agency of Japan
2-5-6 Shiba, Minato-ku, Tokyo 105

Masamichi ISHIKAWA, Yukio INOUE and Shinichi KAMEI

Mitsubishi Research Institute, Inc.
2-3-6 Otemachi, Chiyoda-ku, Tokyo 100

Solidification of semiconductors, metals,,alloys, and organic materials has been main research objects of microgravity investigations. So the development of techniques to simulate solidification is beneficial to microgravity experimenters.

To evaluate the validity of the Stefan-type analysis, numerical solution of moving boundary problems was applied to the melt growth of succinonitrile, cyclohexane, and pure water with careful adjustment of thermal boundary conditions. Supercooling was observed for all samples, causing considerable differences from the Stefan-type solutions at the beginning of the solidification. The Stefan-type solution showed maximum values of observed growth thicknesses. Diffuse interface model was introduced to explain the deviation from the conduction growth mechanism due to supercooling.

Key words: Stefan Problem, Diffuse Interface Model, Solidification

POOL-BOILING EXPERIMENTS UNDER MICROGRAVITY --DEVELOPMENT OF EXPERIMENTAL APPARATUS FOR PARABOLIC FLIGHT MANEUVERS--

*Toshiharu OKA, **Yoshiyuki ABE, **Kotaro TANAKA,
*Yasuhiko H. MORI, and *Akira NAGASHIMA

* Faculty of Science and Technology, Keio Univ.
** Energy Systems Division, Electrotechnical Laboratory

A compact pool-boiling cell has been constructed for the use in parabolic aircraft-flight experimental program scheduled for 1989/1990 winter season. The cell is equipped with a plate heater to boil saturated or subcooled liquid of n-pentane and with a metal bellows to compensate a volume change of pentane in boiling. The heater consists of a metal foil to be Joule-heated, which is lined with a thermotropic liquid-crystal layer and then laid on an epoxy-resin base. The side view of vapor bubbles growing on the foil surface and a color map exhibited by the liquid-crystal layer responding to the dynamic behavior of the bubbles are recorded simultaneously by use of a high-speed VTR. Some terrestrial experiments to test the experimental facilities are under way.

Keywords: Pool-Boiling, Microgravity, Thermotropic Liquid-Crystal

IN-SITU OBSERVATION OF SOLIDIFICATION PHENOMENA OF SOME ORGANIC MATERIALS AS A METALLIC MODEL

Tetsuichi MOTEGI, Atsumi OHNO and Kazuichiro MINAMI

Chiba Institute of Technology
Tsudanuma, Narashino, Chiba-ken 275

A preparatory study of the solidification mechanism of metals and alloys under microgravity conditions, in-situ observation of the crystal growth of some transparent and low melting organic reagents, showing similar crystal growth of solidifying metals, was carried out on earth.

Remelting and solidifying phenomena of samples enclosed in a glass cell were observed through a microscope. Two types of solidification were observed: Salol and Benzil showed the growth of faceted cells; Carbon tetra bromide, Azobenzene and some other materials showed the dendrite growth.

Precipitation of small crystals from the top of the glass cell during the dendrite growth were observed. This was caused by heat extraction during cooling. Neither dendrite remelting during the growth, nor crystal nucleation in the liquid occurred. These results do not support the theory of the formation of a refined grain zone in the solidified structure caused by dendrite remelting or by nucleation in the liquid which have both previously been proposed by other investigators.

Key words: In-situ Observation, Crystal Growth, Dendrite Growth, Faceted Cell, Refined Grain Zone

In-SITU OBSERVATION OF WATER SOLIDIFICATION

Tetsuichi MOTEGI and Hiroshi YAMAZAKI

Chiba Institute of Technology
Tsudanuma, Narashino, Chiba 275

In order to simulate the solidification processes of metals, water-ice transformation in a transparent plastic container was observed directly through a TV camera.

The experiment was conducted with six different containers, three of which were made of plastic with bottom in contact with an aluminum block. The other three containers had no bottom, and thus were in direct contact with an aluminum block. Each container in the two groups held a different kind of water, these being distilled water, ion-exchanged high purity water, and tap water. These different containers were used for comparison of freezing process.

Each sample in the container with the plastic bottom showed thermal undercooling. The largest undercooling appeared in the ion-exchanged high purity water, and the smallest one in the tap water because of impurities. After the recalescence, ice dendrites formed quickly from the cooling bottom to the top. However, these dendrites disappeared quickly, because of the evolution of latent heat, and then the solid-liquid interface advanced toward the top of the water. In this case, dissolved gases in the water were released and formed a lot of spherical gas bubbles, which were trapped under the solid layer.

On the other hand, no undercooling appeared on the cooling curves, in the water sample that was in the container with the aluminum chill block. A high level of heat transfer through the chill block didn't occur, and the undercooling and the solid-liquid interface advanced slower than that of the dendritic growth as observed in the case of the plastic bottom area.

Key words: Undercooling, In-situ Observation, Dendrite, Gas Bubble, Water-Ice Model

EXPERIMENT SYSTEM FOR IN-SITE OBSERVATION OF SORIDIFICATION PROCESS USING A SOUNDING ROCKET

Hideyo SAKURAI,Tohru WATANABE, Yosito ARAI,
Hirosi MARU and Tkatosi KAWAI
Ishikawajima Harima Heavy Industry
Tonogaya, Mizuhocho, Nisitamagun, Tokyo,

Isao KUDO, Shunsuke HOSOKAWA and Akira IWASAKI
Erectronical Laboratory
Umezono, Tukuba, Ibaraki

The experiment system for in-site observation of unidirectional solidification process under a microgravity condition using MASER-IV (Material Science Experiment Rocket) of Swedish Space Corporation) has been developed. A biphenyl liquid crystal is chosen for a model material. A model material is containd in a glass cell. A temperature gradient is produced during the experiment to cause unidirectional solidification. This solidification process is observed by the Mach-Zehnder interferometer and recorded by a 8mm video tape recorder. The engineering model of the on-board module was conatructed and the groundbased experiment was also made. The flight model of the experiment is under manufacturing based on the experiment using the experimental model and willbe flown in March 1990.

IMAGE PROCESSING OF INTERFERROGRAMS TO OBSERVE SOLIDIFICATION AND CRYSTAL GROWTH UNDER MICROGRAVITY

Fuminori KOBAYASHI+, Shigehiro FUKUSHIMA+, and Kazuhiko KAWAGUCHI++

+ Kyushu Institute of Technology
Kawazu, Iizuka, Fukuoka 820
++ Nagaoka University of Technology
Kamitomioka, Nagaoka, Niigata 940-21
(presently with Nippon-Data General Corp.)

The processes of solidification and crystalization of crystals from liquid phases have not intensively been investigated, partly because of the influence of convection. To clarify the dynamics of solidification and crystalization, some researchers attempt to measure concentration (/temperature) distribution of liquids under microgravity, in which flow is negligible. This study, as a part of such approaches, intends to estimate concentration by processing images observed with interference microscopes. Although smooth interference stripes are required for estimation, original images are degraded with speckles and artefact caused by optical errors. Because of the high level of such noise, traditional local image processing techniques cannot provide for satisfactory results. This note proposes a global scheme by matching the originals with regular stripe patterns.

Key words: Space Materials Experiment, Image Processing, Computer

UTILIZATION OF SPACE FOR THE STUDY OF THE DIFFUSION OF LIQUID METALS

Toshio ITAMI

Department of Chemistry, Faculty of Science,
Hokkaido University, Sapporo 060

The present state of the study of the diffusion of liquid metals have been reviewed. Detailed discussions were given about the recent pioneering experimental results of the diffusion of liquid metals. The previous experimental data of the diffusion coefficient of liquid metals have been suffered from the effects of the convection, which is included by the gravity. Therefore, the diffusion coefficients of liquid metals, as a whole, must be reexamined with the use of gravity-free circumstance of space.

Key words: Space Utilization, Liquid Metals, Diffusion

THEORY OF HOMOGENEOUS NUCLEATION IN MULTICOMPONENT SYSTEMS

Kazumi NISHIOKA, Isamu KUSAKA

Department of Precision Mechanics, University of Tokushima
2-1 Minamijosanjima, Tokushima 770

and

Tadayoshi TAKAI

Faculty of Engineering, Kagawa University
1-1 Saiwai-cho, Takamatsu 760

Containerless experiments in space are expected to provide convincing information on the homogeneous nucleation in liquid phases. Gibbs' formulae for evaluating the reversible work of forming a critical nucleus in a multicomponent system are summarized including the recent developments. The composition of a critical nucleus is determined only by the bulk properties of the parent and the nucleating phases, and is independent of the interfacial tension. Whereas, the radius of a critical nucleus is strongly related to the value of the interfacial tension.

Curvature dependence of the interfacial tension, which includes also the composition dependence, is analyzed and evaluated for the regular solution model by employing the thermodynamics of inhomogeneous systems and the inhomogeneous regular solution model due to Cahn-Hilliard. It is found that the interfacial tension diminishes with the curvature, and the radius of the critical nucleus, the interfacial tension and the reversible work to form a critical nucleus all approach zero as the mean field spinodal composition is approached for the parent phase.

Finally, the conventional formalism for evaluating the reversible work to form a critical nucleus is analyzed, and it is found that it approximately results in Gibbs' formulae when the curvature and the composition dependence of the interfacial tension is neglected.

Key words: Homogeneous Nucleation, Interfacial Tension, Curvature Dependence, Critical Nucleus, Multicomponent System

IN SITU OBSERVATION OF ICE CRYSTAL GROWTH FROM LIQUID

Yoshinori FURUKAWA

Institute of Low Temperature Science,
Hokkaido University, Sapporo 060

Growth patterns of ice crystals grown from the supercooled water were observed in situ using a schlieren optical system combined with a TV camera. The ice crystal was grown at the tip of glass capillary inserted in a glass cell (20mm x 20mm x 50mm).

The growth patterns of ice crystals change from circular-disks, to perturbed disks and to dendrites. At the low supercooling, the morphology of ice crystal showed the roughly hexagonal symmetry. This result reflects the anisotropy of surface free energy for the crystallographic faces perpendicular to the (0001) face. In addition, several characteristics of the ice crystal growth were shown preliminary.

The formation mechanism of the dendrites, the influence of the anisotropy of surface free energy for the ice crystal patterns and the effect of the free convection in water surrounding the crystal for the growth rate and the growth patterns will be studied using this experimental apparatus in future.

Key words: Ice Crystal Growth, Instability, Free Convection

DENDRITIC GROWTH WITH CONVECTION

Yasunori MIYATA and Martin E. GLICKSMAN

Nagaoka University of Technology
Kamitomioka, Nagaoka 940-21
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

Dendritic growth theory in the supercooled melt is developed for the growth with forced flow and then applied to the growth with natural convection by the thermal-convection analogy.

Dendritic interface is assumed to be a paraboloid of revolution and the melt flow is analyzed. The temperature fields in the liquid and in the solid are derived, which are consistent with the flow. The crystalline anisotropy is introduced and local equilibrium conditions on the dendritic interface are imposed. For a given supercooling and a given forced flow, the growth rate and the tip radius of a dendrite are predicted. The predictions are compared with experiments.

One influence of the forced flow, at fixed thermal supercooling, is shown to increase the growth velocity and correspondingly decrease intrinsic crystal dimensions(tip radius). The morphological influence of the flow becomes stronger as the growth velocity becomes smaller.

Finally, the theory is extended to include the effect of gravitationally-induced buoyancy flow. The thermal-convection analogy is applied, which approximates the buoyancy flow by the corresponding forced flow.

These studies clearly underscore the importance of gravitationally -induced buoyancy effects on crystal growth kinetics and morphology.

Key words: Solidification, Dendrite, Buoyancy Flow, Gravitational Effect

FUNDAMENTAL STUDIES ON ELECTROCHEMICAL PROCESSINGS UNDER SUPERCONDITIONS

Yasuhiro FUKUNAKA, Zenjiro ASAKI, Kenji SUMIYAMA and Yasuhiko ITO

Faculty of Engineering, Kyoto University
Yoshida-Honmachi, Sakyo-ku, Kyoto 606 Japan

ABSTRACT

Electrochemical processing for tailored materials in space satellite is proposed, where processing energy is supplied with a thermoelectric power generator. Candidate materials to generate a large electromotive force due to the overall entropy change on electrode reaction must be exploired. Moreover, the reversibility of thermoelectric cell must be assured. At the same time, to establish an extremely steep temperature gradient is the key factor to sucessfully operate this thermoelectric power generator. Space provides a most attractive surrounding in this sense. Holographic interferometry was applied to simultaneously measure the temperature and concentration profiles formed near the interface during solidification and electrodeposition. Accumulating these foundamental studies, the concept of satellite for electrochemical processing for tailored materials may become fruitful. An example of such electrochemical processings in space is levitation electrolysis. Deoxidation kinetics of levitated metal droplet is now studied focusing the hydogen solubility into molten metals.

Key words: Electrochemistry, Electrochemical Processing, Superconditions, Thermoelectric Power Generator, Laser Holographic Interferometer, Interfacial Phenomena, Extreamly Steep Temperature Gradient,

TYPE II STRIATION UNDER MICROGRAVITY

---Origin and Way to Suppress---

T. Nishinaga*, K.W. Benz** and A.N. Danilewsky**

* Department of Electronic Engineering, The Faculty of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyoku, Tokyo 113, Japan

** Institute of Crystallography, University of Freiburg, Hebelstrasse 25, D-7800 Freiburg, FRG

Type II striation formed during the THM growth under microgravity is studied theoretically and experimentally. It was found that type II striation appeared in the beginning and the end of the growth where the growth velocity was supposed to be high. The interface concentration profile of the solute is calculated around the macrostep the movement of which causes the type II striation. It is concluded that the growth velocity and the temperature gradient perpendicular to the growth front are the key factors for the creation and the extinction of the macrostep and hence the type II striation.

Key warda: type II striation, macrostep, microgravity

GROWTH OF SEMICONDUCTOR MIXED CRYSTALS

Masashi KUMAGAWA, Kazuhiro ASAKAWA, Yoshihumi TORIMOTO
and Yasuhiro HAYAKAWA
Research Institute of Electronics, Shizuoka University
3-5-1 Johoku, Hamamatsu, Shizuoka, 432

The influence of the solution flow due to the thermal convection was investigated in the growth experiment of $In_xGa_{1-x}Sb$ mixed crystals using a conventional LPE apparatus.

Two types of boats were employed to mount a GaSb substrate vertically or horizontally in the source solution. They were designed so as to pass electric current across the solution-substrate interface. The composition ratio of the solution source, In:Ga:Sb was selected as 32:38:30 at%, respectively. The crystal growth was initiated from 600°C at a constant cooling rate of 10°C/h, and was sustained for 4 h. During growth, electric current pulses for forming markers into the crystal layer were introduced at intervals of 30 min. Grown samples were cut along the growth direction, and their growth morphologies were observed .

In the vertical-mounted experiment, the growth morphology on the plane cut longitudinally showed that the thickness of the grown layer was more thick in the upper region than the lower one at the initial stage of growth. On the other hand, from the transverse cut plane, the layer grew flatly at first and then in a reformed-sawtooth shape. This suggests that a convection occurred in the solution gave an influence locally to the boundary layer and as a result the growth rate was modulated. Macroscopic average growth rate was decreased abruptly with growing. This will be due to the segregation of solute oversaturated by the temperature lowering.

In the horizontal-mounted case when the substrate was placed on the solution surface, the substrate-grown layer interface was fairly rough because of the washing by the solution convection. This tendency was the same even if the polarity of the substrate surface was changed from (111)A to (111)B. When the substrate was put at the bottom of the solution, on the contrary, the interface was considerably well in flatness and the grown layer had almost constant thickness. The growth rate showed the maximum value at about 40 min after growing and then decreased gradually. This variation in growth rate was found to be agreed with that calculated from a solute diffusion model. This means that the crystal growth was not directly affected by the convective flow.

In conclusion, the influence of the solution convection on the crystal growth was clear by using the substrates put vertically and horizontally.

Key word : convective solution flow, mixed crystal growth,
liquid phase epitaxy, III-V semiconductor

RESIDUAL IMPURITIES OF MELT-GROWTH InSb

Isao OHNO

Electronics Department,Tamagawa University
Machida,Tokyo 194

A correlation between crystal preparation and galvanomgnetic measurement at77k is described on high purity Melt-Growth InSb available now , with the aim of developing a new crystal preparation method and/or process in space. Experimental results of heat treatment are mainly shown. Conclusively,a closed processing system is proposed; synthesis of starting material,formation of ingot,and zone-refining are carried out in a same apparatus in space; combining with CZ and FZ apparatuses.

Key words:Preparation,High Purity InSb,Space

IN-SITU OBSERVATION OF DISSOLUTION AND CRYSTAL GROWTH IN COMPOUND SEMICONDUCTOR

Kazuhiko KURIBAYASHI

Institute of Space and Astronautical Science
Yosino-dai, Sagamihara, Kanagawa 229, Japan

Surface morphologies of grown layers vary with crystal growth conditions in semiconducting materials. Macrosteps, which are responsible to formation of impurity striations, have been investigated quantitatively with respects to their morphological instabilities, the growth kinetics for formation of macrosteps, however, have not been quantified because of their difficulties in observations of initial stages of macrostep formations. In-situ observation of grown layers can be expected to provide the direct information of morphological variations. Most semiconducting materials are transparent for infrared rays. It is possible, using infrared rays, to observe the liquid/solid interface from the bottom side of the substrate during the process of solution growth. Direct observation technique, developed in the present experiment, successfully gives clear images of morphological variations of grown surfaces in GaP crystal.

Key words: In-situ observation, Crystal growth, Compound Semiconductor

USE OF A TEMPERATURE OR A SALT CONCENTRATION GRADIENT FOR GROWING PROTEIN CRYSTALS

Mitsuo ATAKA, Yasuo BESSHO and Michihiko ASAI

Research Institute for Polymers and Textiles, AIST
1-1-4, Higashi, Tsukuba 305

We proposed in 1977, as a method of growing large single crystals of proteins, the use of a gradient of either temperature or salt concentration. Possible advantages of this method are discussed in relation to experiments under microgravity.

First, it is shown that the solubility of tetragonal form crystals of hen egg-white lysozyme exhibits three- to four-fold changes, when the temperature is raised from 5 to 15°C, or when the NaCl concentration is decreased from 6 to 3%. It is then manifested that the change of either temperature or salt concentration of this magnitude can easily be made within a long vessel containing an aqueous protein solution. When such a gradient is formed in a solution of certain protein concentration, the degree of supersaturation, which means the difference between the solution concentration and solubility, varies in accordance with the changes in solubility. Namely, the gradient of either temperature or salt concentration is equivalent to the gradient of the degree of supersaturation. It is also shown that this degree of supersaturation largely governs the size of crystals and the period needed for their growth.

If experiments are carried out under a gradient, it will be possible to observe the crystal growth in a range of supersaturation. A search within a certain range of supersaturation may be favored in space experiments, since the degree of supersaturation greatly affects both the crystal size and crystal formation period, and since the optimal supersaturation under microgravity is not easily predictable. In addition, if the crystals start to grow only in a part of the vessel as is usually the case in an experiment using a gradient, then the unavoidable subsequent decrease in solute concentration is compensated by the molecular supply from the other part, in which the crystals do not grow. Continuous supply of solute molecules to growing nuclei will also contribute to the availablility of large crystals.

The operative parameters in designing a gradient experiment are initial protein concentration, magnitude of the gradient, and the size and shape of the vessel. For a salt concentration gradient, the kind of salt, and temperature can also be chosen independently. The advantage of the gradient method depends on the proper selection of these variables.

Key words: Protein crystal growth, Gradient method, Temperature gradient, Salt concentration gradient

Pre-Experiments on the Earth for Crystal Growth of Organic Superconductor TTF[Ni(dmit)$_2$]$_2$ for IML-1

Aiko Muramatsu[1], Seiichiro Yamamoto[1], Hiroyuki Anzai[2] Kazumasa Honda[3], Akio Kanbayashi[4]

Institute of Research and Innovation[1], Electrotechnical Laboratory[2], National Chemical Laboratory[3], National Space Development Agency of Japan[4]

Organic metals and organic superconductors have unique properties that usual ones do not have. Therefore, it is expected that new electronic materials and elements are derived from them. In order to reveal intrinsic properties of organic metals and organic superconductors, those large and good qualified crystals must be obtained. The crystals of organic metals and organic superconductors are grown by a method of diffusion of donor and acceptor in organic solvents. The diffusion is not realized at all on the earth because thermal convection and gravity. But, ideal diffusion can be realized under the microgravity, for example, on the space shuttle. In this work, the crystal growth of organic superconductor TTF[Ni(dmit)$_2$]$_2$ by diffusion process were studied for the plan of IML-1. It is expected that large and good qualified crystal of TTF[Ni(dmit)$_2$]$_2$ is obtained by the ideal diffusion under microgravity.

In order to carry out crystal growth of TTF[Ni(dmit)$_2$]$_2$ by complicated double decomposition between (TTF)$_3$(BF$_4$)$_2$ and Bu$_4$N[Ni(dmit)$_2$], and in order to use the crystal growth cell developed for FMPT for the organic superconductor, solubility of the started reagents in several solvents and crystal growth condition were studied. It was found that $(CH_3)_2CO$, CH_3CN, CH_3NO_2, $C_6H_5NO_2$, C_6H_5CN and $C_6H_5COCH_5$ were suitable solvents for the crystal growth of TTF[Ni(dmit)$_2$]$_2$, and that the crystal growth cell for FMPT was useful sufficiently for the organic superconductor. The crystal growth of TTF[Ni(dmit)$_2$]$_2$ by double decomposition between (TTF)$_3$(BF$_4$)$_2$ and Bu$_4$N[Ni(dmit)$_2$] in organic solvents was favorable under an atmosphere of nitrogen gas.

Key word: Organic superconductor, Diffusion, Crystal growth.

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